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EVALUATING THE EFFECTIVENESS OF MAINTENANCE TRAINING BY USING CURRENTLY AVAILABLE MAINTENANCE DATA

J. String
J. Orlansky

August 1981

Prepared for

Office of the Under Secretary of Defense for Research and Engineering

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Five maintenance management systems were investigated. Three of these appear to offer no prospect of assessing maintenance performance, due primarily to the way maintenance organizations are structured. The remaining two systems may provide a restricted capability for assessing performance with some modest changes to the data reported through the systems. The effect of the suggested data-reporting changes would be to identify maintenance actions that are not suitable for assessing performance, but the question remains of whether the remaining sample of maintenance actions would adequately represent ~~of~~ the job requirements of different skill areas.

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EVALUATING THE EFFECTIVENESS OF MAINTENANCE TRAINING BY USING CURRENTLY AVAILABLE MAINTENANCE DATA

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August 1981

INSTITUTE FOR DEFENSE ANALYSES
SCIENCE AND TECHNOLOGY DIVISION

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ABSTRACT

Costs of training military personnel in maintenance skills comprise a significant portion of total military training costs. The effectiveness of maintenance training is currently measured only by student achievement at schools, and correlations between school achievement and on-the-job performance have not been established.

The military services currently employ extensive systems for day-to-day management of maintenance operations. If the data generated and reported through these systems could be used to estimate the performance of either maintenance organizations or the individuals assigned to them, they provide information needed to determine the effectiveness of alternative methods of training maintenance personnel.

Five maintenance management systems were investigated. Three of these appear to offer no prospect of assessing maintenance performance, due primarily to the way maintenance organizations are structured. The remaining two systems may provide a restricted capability for assessing performance with some modest changes to the data reported through the systems. The effect of the suggested data-reporting changes would be to identify maintenance actions that are not suitable for assessing performance, but the question remains of whether the remaining sample of maintenance actions would adequately represent the job requirements of different skill areas.

CONTENTS

SUMMARY

A. PURPOSE

This paper assesses the possibility of using data generated by the maintenance management systems of the military services to evaluate the effectiveness of alternative methods of training maintenance personnel.*

B. BACKGROUND

Costs of training maintenance skills comprise a significant portion of the $3 billion spent each year for technical training at military schools and can be expected to increase with increases in the complexity of weapon systems. On the other hand, the potential costs of "inadequate" maintenance, in terms of increased operating costs and reduced operational capabilities, may be considerably greater than the costs of providing more extensive and more effective maintenance training.

Training effectiveness is currently measured only by student achievement at schools. However, the true effectiveness of training lies in the performance of personnel on-the-job, and the comparative effectiveness of different amounts and methods

*In 1976, the Defense Science Board recommended cost-effectiveness evaluations of military training. This study is one of several undertaken in response to that recommendation. The study was performed for the Office of the Deputy Under Secretary of Defense for Research and Engineering (Research and Advanced Technology), under the technical cognizance of the Military Assistant for Training and Personnel Technology.

of training should be measured by comparing on-the-job performances of personnel trained in different ways.

Correlations between school achievement and on-the-job performance of maintenance personnel have not been established, and the development and operation of a data system for this purpose would be a costly undertaking. However, the military services currently employ extensive systems for the day-to-day management of their maintenance operations, and these systems generate extensive historical data. If these data could be used to shed light on the performance of either maintenance organizations or the individuals assigned to them, they might also provide information that would be helpful in determining the effectiveness of alternative methods of maintenance training.

C. DATA REQUIREMENTS

Assessment of the effectiveness of alternative methods of training must be based on comparative analysis; this levies stringent constraints on the content and format of the historical data. Comparisons of maintenance performance require that:

1. Criteria of performance can be formulated and their measures quantified from the historical data;
2. Similar maintenance operations can be identified and grouped; and
3. Maintenance operations can be associated with the individuals or groups performing them.

Translating maintenance performance into comparisons of training effectiveness requires that:

1. The groups of similar maintenance tasks can be related to skill-areas associated with particular training programs and
2. The individuals or groups performing the maintenance can also be related to skill-areas associated with particular training programs.

These constraints appear to be satisfied only when the data encompass all (or a representative sample) of the maintenance operations performed on all (or a representative sample) of the equipment holding of a military service and provide unambiguous (i.e., coded or keyword format) answers to the following four questions:

1. What equipment was maintained? The equipment must be identified at a sufficiently low level (e.g., subsystem or component) so that maintenance can be associated with a single skill-area that can be related to specific training.
2. What maintenance operation was performed? The data must separately document discrete small-scale maintenance tasks (e.g., remove, disassemble) that are comparable whenever they are performed on the same subsystem or assembly installed on the same model of equipment end-item, rather than documenting a complete maintenance action (i.e., the repair of an item of installed equipment that permits return of the end-item to service) that may require different skills and levels of effort, depending upon the precise nature of the malfunction.
3. Who performed the maintenance? Maintenance organizations are typically manned to provide the variety of skills required by all weapon end-items maintained. Documentation of maintenance must identify the individuals or elements of the organization performing maintenance in a manner that can be related to skill-area (e.g., work-center).
4. Why was maintenance required? Reasons for performing the maintenance may (or may not) be required to determine comparability between maintenance tasks. For example, the task of removing a particular subsystem or assembly from an end-item is the same, regardless of

why the assembly is removed, while the skill and effort required to effect its repair, per se, may differ widely as a function of why maintenance is required.

D. THE IMPACT OF TEAM AND CROSS-SKILL MAINTENANCE

Beyond considerations of data requirements, two common practices in military maintenance preclude an assessment of training effectiveness -- team maintenance (the assignment of two or more individuals to a maintenance task) and cross-skill maintenance (performance of maintenance in one skill-area by personnel who have been trained in other skills). Several reasons lie behind team maintenance, including on-the-job training (OJT), size of equipment undergoing maintenance or its proximity to test equipment, expediency in returning end-items to operational status, and the utilization of maintenance facilities. In assessing training effectiveness, interest must center on recently trained individuals before the differential effectiveness of different methods and amounts of training is diluted by subsequent OJT and experience. However, maintenance teams would typically be composed of individuals with differing levels of experience and/or training and the recently trained personnel would have little impact on overall team performance. In addition, there is no systematic way to quantify the separate contributions of team members.

A number of reasons lie behind cross-skill maintenance; a primary one is that of providing personnel with OJT in additional skill-areas to enhance maintenance organizations' capabilities to satisfy the increased (and more variable) workloads anticipated under combat conditions. However, the effectiveness of training in a given skill-area can be assessed only where maintenance performance is measured in tasks in that skill-area by individuals who have been trained in that skill.

Since neither team nor cross-skill maintenance provide a valid basis for assessing training effectiveness, historical maintenance data would have to allow for identification of occurrences of both so that their occurrences could be eliminated from analyses.

E. EVALUATION OF MAINTENANCE MANAGEMENT SYSTEMS

Five maintenance management systems were investigated: The Army Maintenance Management System (TAMMS), the Navy Ships' Material Maintenance Management (Ships' 3-M) system, the Navy Aviation Material Maintenance Management (Aviation 3-M) system, and the Air Force 66-1 and 66-5 systems. Taken together, these systems control the management of organizational and intermediate maintenance of all military aircraft, all Army and Air Force ground equipment (including missiles), and all Navy ships and shipboard equipment (except nuclear missiles). Table S-1 displays the attributes of the data each generates in terms of the data requirements discussed above. (Since the Air Force 66-1 and 66-5 systems employ the same reporting formats and codes they are combined in the table.)

On the basis of data reported, the Ships' 3-M system appears to have no capability for assessing maintenance performance (and, hence training effectiveness) for reasons that encompass both the nature and extent of data reported. A critical point is that the majority of maintenance activities are not reported in this system.

TAMMS also appears to provide no capability for assessing training effectiveness. Army maintenance employs extensive cross-skill and team maintenance. Since the reported data contain no means for identifying the skill-areas (and hence training) of personnel performing particular maintenance tasks, it appears impossible to track cases of cross-skill work. Further, maintenance organizations are staffed to rely on team maintenance

TABLE S-1. ATTRIBUTES OF HISTORICAL MAINTENANCE DATA

Attributes of Historical Data	Maintenance Management System			
	TAMMS (Army)	Ships' 3-M (Navy)	Aviation 3-M (Navy)	66-1/66-5 (Air Force)
Encompasses all or a representative sample of the maintenance operations performed on all or a representative sample of the equipment inventory.	Yes	No	Yes	Yes
Provides a measurement of maintenance performance.	Yes	Yes	Yes	Yes
Describes what equipment was maintained in a coded or key-word format and at an equipment level (e.g., subsystem or component) that can be associated with particular skill-areas and training programs.	Yes	No	Yes	Yes
Describes what maintenance operation was performed in a coded or key-word format and in terms of small-scale, well-defined tasks that are comparable when performed on the same item of equipment.	Yes	No	Yes	Yes
Describes who performed the maintenance in terms of individuals or work centers that can be associated with particular skill areas and training programs.	No	Yes	Yes	Yes
Describes why maintenance was required in a coded or key-word format and showing the final malfunction diagnosis.	Yes	No	Yes	Yes

involving different maintenance echelons under combat conditions, and it is unclear how its occurrence could be traced in the historical records.

The Aviation 3-M and Air Force systems satisfy data requirements set out in Table S-1 and may provide some capabilities for assessing training effectiveness. The principal question involves whether team and cross-skill maintenance can be identified, and this should be facilitated with some seemingly modest changes to the data reported and by supplementing those data with information that is normally available from unit roster and personnel record systems.

The Air Force 66-1 and 66-5 systems currently document maintenance "crew size" and start and stop times and provide a separate entry for all crew changes and work interruptions that occur during the course of a maintenance task. These data, if accurately recorded, should provide a satisfactory separation of team maintenance from individually performed maintenance. Aviation 3-M currently provides no permanently retained information regarding the number of individuals involved. However, the similarities in equipments, their maintenance requirements, and maintenance organizations between USAF and Naval aircraft suggest that information on the composition of maintenance crews could be readily incorporated into Aviation 3-M data.

Identification of cross-skill maintenance presents a more formidible problem. Naval aircraft and Air Force maintenance organizations are structured internally according to skill so that occurrences of cross-skill work should be identifiable. However, a sufficient number of exceptions (conditions under which individuals would be assigned to tasks outside their skill-areas) were noted in documentation of these systems to weaken the case for identifying cross-skill work. Cross-skill maintenance is a formidable problem for Air Force units operating within the 66-5 system where development of cross-skill capabilities is a policy objective.

This would present no problem if the individuals performing maintenance could be positively identified (through, e.g., name or social security number). At present, neither Aviation 3-M nor the Air Force systems provide this identification, and provisions of the Privacy Act prevent naming of individuals in permanent central historical data files. However, it does not prevent such identification in local unit temporary records (such as work-in-process logs). Local unit naming of personnel should provide an early positive screening for instances of cross-skill maintenance. For example, individuals could be preselected for analysis of their performance on the basis of training and experience information gleaned from personnel records. Where maintenance documentation identified these individuals and where neither team nor cross-skill maintenance was indicated, the local records could be duplicated for analysis of performance and training effectiveness, with the personnel identification being deleted. The Navy is currently modifying the local unit portion of Aviation 3-M in a manner that appears compatable with this concept, and there is no reason to believe that the Air Force management systems are basically incompatable with it.

Even with these changes, the nagging question remains of whether the resulting performance samples would be representative of the job requirements of the various skill areas. The prospects are not promising, especially for organizational echelon maintenance. Recently trained personnel typically are not assigned to independent work on aircraft equipment, and this is the population of interest for assessing training effectiveness. Team maintenance is prompted by features of the equipment and enhances unit effectiveness. Cross-skill maintenance contributes to a maintenance organization's potential under combat conditions.

I. INTRODUCTION

Training costs devoted to maintenance comprise a significant portion of the $3 billion spent each year for technical training at military schools and can be expected to increase with increases in the complexity of weapon systems. On the other hand, the potential costs of "inadequate" maintenance, in terms of increased operating costs and reduced operational capabilities, may be considerably greater than the costs of providing more extensive and more effective maintenance training.

Student achievement in courses at training schools is currently used as the measure of training effectiveness. However, the effectiveness of maintenance training is ultimately determined by the performance of maintenance personnel in the field rather than at schools. It follows, then, that the comparative effectiveness of different amounts and methods of maintenance training should be measured by assessing the comparative performance of maintenance personnel in field assignments rather than by assessing their achievement in school. Of particular interest here would be whether the use of maintenance simulators at schools improves the maintenance performance of students in the field over those trained with actual equipment.

Correlations between school achievement and job performance have not been established; no reports exist that relate performance on-the-job to training in a systematic manner. The development and operation of a data system for this purpose would be a costly undertaking, and for that reason it is relevant to ask whether maintenance data collected for other purposes might also provide data on the effectiveness of maintenance training. The services currently employ large maintenance management systems that vary with respect to formats, methods, and completeness of data recording and reflect differences in types of equipments held and the environments in which they are operated and maintained. All Army equipment is managed through the Army Maintenance Management System (TAMMS). The Navy operates two Maintenance Material Management (3-M) systems--one for aircraft and one for ships.

The Air Force uses two maintenance management systems--the "66-1" and "66-5". (66-1 and 66-5 refer to the numbers of the Air Force Regulations and Manuals that set out policy for each system.) However, both systems employ the same set of maintenance-reporting formats and codes and the same data-processing programs. As a result, they should generate equivalent maintenance data and, through most of this discussion, are treated as a single entity, denoted as 66-1/66-5.

All of these systems are concerned primarily with the daily management of maintenance organizations and with attaining a high level of operational readiness throughout the force. Operational readiness encompasses considerably more than maintenance, per se, and these systems address a variety of functions associated with the general area of logistics, including:

- Manning and manpower utilization
- Weapon system operation or utilization rates
- Weapon system logbook and inventory control
- Modification and configuration control
- Preventive maintenance
- Reliability and safety
- Technical documentation
- Supply support and material control.

It should be noted that none of these systems was intended (or designed) to reflect training effectiveness. To the extent that they may provide this capability is serendipity.

Both the Navy Aviation 3-M and the Air Force 66-1/66-5 systems compile permanent historical records of all maintenance performed. In the Ships' 3-M system an unknown proportion of maintenance is compiled in historical files. In TAMMS, information is recorded at the local level on all maintenance activity. However, these records are retained only for a limited time, and centralized reporting is limited to modifications of equipment. If these historical records can be used to assess maintenance performance (of either individuals or organizations), they may also provide information that can be associated with the effectiveness of alternative methods of maintenance training. Interest must center on the performance of recently trained personnel, since subsequent on-the-job training and field experience will dilute the impact of formal training on performance. As a result, it is important to know when personnel complete training school courses.

Assessing maintenance performance requires: (1) that criteria of maintenance performance can be formulated and (2) that maintenance data are formatted in historical records in ways that can be related to the criteria. Training effectiveness might then be assessed by comparative analyses of maintenance performance between sets of individuals, that are differentiated on the basis of training received, on the same or similar sets of maintenance operations, provided that (1) data are formatted in historical records so that like or similar maintenance jobs can be identified and grouped, (2) the groups of similar jobs can be related to skill areas associated with particular training programs, (3) the groups associated with each skill area provide a representative sample of the maintenance operations performed within that skill area, (4) the historical records associate maintenance jobs performed with individuals or organizations performing them, and (5) the individuals or organizations can be linked to skill areas associated with training programs.

The approach adopted here is to formulate criteria of performance of maintenance personnel and to identify the types of data that would permit relating observed on-the-job maintenance performance to type of training. The four maintenance data reporting systems are then examined to see how closely they provide the required data. Only organizational and intermediate maintenance echelon reporting systems are considered, since depot maintenance is accomplished, typically, by civilian personnel. Throughout the discussion maintenance action is defined as "all effort associated with the completion of maintenance requirement," e.g., the correction of a malfunction permitting return of equipment to an operational status. Maintenance task is defined as "a single procedure that is performed as part of a maintenance action," e.g., remove, troubleshoot, repair, and install are discrete parts of a single maintenance action that corrects an equipment malfunction.

II. CRITERIA OF PERFORMANCE

Many criteria could possibly serve as partial or general indicators of maintenance performance. Only three are discussed below, on the basis that they are familiar and quantifiable, have general applicability, and offer widely varying capabilities to isolate maintenance performance from other factors that represent force operating capabilities.

A. OPERATIONAL (COMBAT) READINESS

This is the ultimate (and commonly used) criterion of overall unit performance. Readiness is a global measure that is affected by a wide range of influences other than maintenance, such as operating budgets, availability of spare parts, equipment operator skills, and system reliability. The amount of time equipment is not operationally ready due to maintenance requirements (NORM) is a commonly used measure of unit maintenance performance; however, it appears impossible to relate the time periods an equipment is in a notoperationally-ready or a reduced-material-condition status to particular maintenance jobs or to equipment subsystems or maintenance skill areas.

B. MAINTENANCE MAN-HOURS PER OPERATING HOUR

This measure is typically associated with evaluations of weapon reliability and maintainability. It can provide a measure of maintenance performance when man-hours expended maintaining particular subsystems can be compared among units operating similar equipment. However, it provides only a gross measure of performance since it cannot distinguish the impacts of different operating environments on maintenance requirements; operating environments would have to be normalized in order to assess effectiveness of different methods of maintenance training.

C. MAINTENANCE MAN-HOURS PER MAINTENANCE REQUIREMENT (ACTION OR TASK)

This measure appears superior to the other two in isolating maintenance performance in a way that might permit performance to be related to training effectiveness, especially where requirements can be stated in terms of maintenance tasks (as defined above). Each of the four reporting systems examined provides explicit statements of man-hours expended in each recorded maintenance requirement. This measure is adopted as the sole criterion of human performance in the following discussion.

III. DATA REQUIREMENTS FOR ASSESSING MAINTENANCE PERFORMANCE

Assessment of training effectiveness must be based on comparative analysis. The validity of the analysis will rest upon limiting comparisons to performances of maintenance personnel on similar maintenance operations (i.e., similar processes applied to the same models of equipment) where personnel have been trained in the same skill areas, but perhaps by different methods or to different extents. Verifying that these conditions are met places several constraints on the data that should be developed, as follows.

A. CODING OF DATA

The data must provide unambiguous answers to four questions regarding each maintenance operation:

- What equipment was maintained?
- What was done to it (i.e., the nature of the maintenance performed)?
- Why was maintenance required (i.e., the nature of the equipment malfunction)?
- Who performed the maintenance?

Unambiguous answers imply that data be reported through keyword or code systems. Note, though, that use of codes and keywords places limits on the way and the detail with which maintenance may be described and these limits may introduce other ambiguities into the data. This consideration forms the basis for some of the remaining data constraints.

B. IDENTIFICATION OF EQUIPMENT

The data must identify the equipment maintained at a sufficiently low level (e.g., subsystem or assembly) so that it can be associated with a single skill area relatable to specific training programs. Maintenance of complex military end-items involves a wide range of maintenance skills, so that identification of end-items provides no information regarding the skill area employed. However, end-items are typically composed of a number of subsystems and assemblies that can be associated with single skill areas, and individual maintenance tasks normally involve a single subsystem or assembly. As a result, maintenance documentation may shed light on training effectiveness only if the equipment undergoing maintenance is identified in a way that also identifies the associated skill area.

A further point with regard to equipment identification is that comparisons of performance are valid only where the same item of equipment is involved. However, assuring that equipment is the same may require more than the use of a code structure. Regardless of its complexity, a code system may be insensitive to differences in end-item or subsystem configurations (such as the use of different models of "black boxes" with similar physical and operating characteristics or different locations of the same model of black box) that can require different maintenance procedures. Where equipment is not standardized, information from outside the reporting system may be required to assure that configurations are identical.

C. DESCRIPTION OF MAINTENANCE PERFORMED

Describing what was done in the course of maintenance involves two considerations. The first is simply that sufficient code values are available to adequately distinguish between different maintenance requirements. The second concerns the magnitude of maintenance effort that is separately documented. Individual maintenance records can, alternatively, document each of the small-scale discrete maintenance tasks comprising a maintenance action, some partial aggregation of tasks required by a maintenance action, or a complete maintenance action. However, to evaluate maintenance performance, the records must separately document discrete and well-defined maintenance operations that are comparable whenever they are performed on the same subsystem or assembly (black box) installed on the same model of equipment end-item.

Typically, military equipment is complex, and a wide range of maintenance requirements can be associated even with relatively small subsystems and assemblies. The use of code systems may place severe limitations on the ways available to describe what is entailed in maintenance actions. Different actions, that can best (or only) be described by the same code value, may require significantly different levels of skill and amounts of effort. For example, low power output from a particular electronic assembly may arise from a number of causes, and the skills and effort required to accomplish correction will vary with the cause. In some cases, correction may be accomplished without removing equipment from the end-items on which they are installed, i.e., on-equipment repair. In other cases, it may be necessary to remove, "bench" repair, and reinstall, i.e., make off-equipment repair. While these are not comparable maintenance efforts, the differences between them are hidden by documenting only the overall task, e.g., repair of the assembly.

Maintenance actions involve discrete smaller scale maintenance tasks (e.g., remove, disassemble, troubleshoot, replace parts, assemble, reinstall) that are well defined, recur frequently as elements of disparate maintenance actions, and constitute comparable maintenance when applied to one model of subsystem or assembly installed on one model of end-item. As a practical matter, documentation of standardized tasks appears to be a necessary condition for assessing maintenance performance. Further, the number of different standardized tasks involved in performing maintenance appears small enough to be incorporated within feasible code systems.

D. DESCRIPTION OF MALFUNCTIONS

Reasons for performing maintenance (i.e., the nature of malfunctions) may or may not be necessary to identify comparable maintenance tasks, depending upon the type of task performed. For example, the task of removing a particular subsystem or assembly (e.g., a communications receiver) from a given model of aircraft involves the same skill and the same amount of work, regardless of the reason maintenance is required. On the other hand, the skills and effort involved in the actual repair of the assembly may differ widely as a function of why the maintenance is required (e.g., consider the difference between replacing a burned out indicator bulb and correcting RF signal distortions).

We have no way of quantifying the proportion of maintenance tasks for which malfunction descriptions will be necessary. The proportion probably varies with the type of system being maintained. However, it can be expected that such descriptions will be required where maintenance involves repair, per se, of equipment.

E. IDENTIFICATION OF PERSONNEL

The data must identify organizations (or individuals) performing maintenance in a way that will allow their association with skill areas that can be related to specific training programs. Documentation of individual maintenance tasks can alternatively identify the individual performing maintenance (who can be associated with skill area and training received through other data, such as personnel records), work centers or shops that are manned by personnel predominantly trained in a single skill area, or work centers and maintenance organizations that encompass a range of skill areas. Cases of maintenance performance that are valid for assessing training effectiveness are limited to those in which the skill area required by the task (as identified through equipment codes) is the same as that in which the personnel performing the task have been trained. As a result, maintenance documentation can shed light on training effectiveness only if personnel performing maintenance can be identified in a way that also identifies their skill areas.

1. Single Individuals

If individuals were identified in maintenance documentation, assessment of training effectiveness could be based on direct comparisons of the performance of personnel, trained in the same skill area by different methods or to different extents, on similar maintenance tasks. However, the prospects for making assessments in this manner appear small. Provisions of the Privacy Act prevent reporting of the performance of individuals to service-wide data bases (such as the central files of the maintenance management systems). If local unit records identify individuals, the records cannot be collated and evaluated above some intermediate organizational level. While this does not prevent their use for evaluation of training effectiveness, it implies recourse to special data collection or processing methods.

2. Work Center

Where individuals are not identified in maintenance documentation, theoretically it should be possible to provide some measure of training effectiveness, if the documentation identified the work center (WC) performing maintenance, for those WCs that are predominantly manned by personnel trained in a single skill area. Different maintenance organizations reporting through the same management system have similar WC structures. If (1) WCs could be characterized in terms of the training received and experience possessed by their assigned personnel, and (2) if samples were gathered, across different maintenance organizations, of the performance of the same WC performing the same maintenance task on the same item of equipment, then (3) inferences regarding training effectiveness might be drawn by regressing WC performance against training and experience profiles within the context of models of the impact of training on performance.

The likelihood that differences in performance among WCs can be confidently attributed to differences in training does not appear promising. The impact of differences in training programs are most relevant for recently trained personnel, and such personnel will have relatively little impact on overall WC performance. A number of other factors, internal to the maintenance organization, affect maintenance performance (e.g., the quality of supervision and the extent to which daily workloads are used for OJT). It could well be that sample sizes necessary to attribute significance to the impact of training could not be obtained.

3. Maintenance Organization

Where maintenance documentation identifies only maintenance organizations (or WCs that are associated with a number of skill areas) it would appear impossible, as a practical matter, to relate performance to training effectiveness. All the considerations discussed in regard to skill-related WCs also are relevant here. In addition, weapon systems are complex and require the application of a number of maintenance skills; maintenance organizations are generally large enough to encompass a large number of skill areas, and the proportion of total personnel trained in a single skill area would typically be small. While theoretically it may be possible to assess training effectiveness through modelling and regression analysis, it appears that requisite sample sizes would be much larger than those required when skill-related WCs are identified.

F. EXTENT OF MAINTENANCE DOCUMENTATION AND REPORTING

The job requirements of any maintenance specialty encompass a host of distinct tasks employing a variety of skills which a training program must provide. Assessment of training effectiveness must address performance across a sufficiently wide range of tasks to provide a representative sample of the skills that are, in fact, employed on the job. While documentation of all maintenance would provide such a representative sample, it is not necessarily a requirement for daily management and may interfere with higher priority functions of a maintenance unit. Efficient unit operations may imply a systematic exclusion of documentation of certain types of maintenance, documentation for certain types of equipment (end-items or subsystems), and documentation of equipments in certain types of assignments. In these cases, data that are gathered may not encompass all relevant skills, and the extent to which they fall short may not be discernible. In addition, local level documentation may not be fully reported to higher echelons or centralized data banks. Such an unavailability of data at more convenient sources reduces the practical usefulness of the maintenance management systems for assessing training effectiveness.

G. IDENTIFICATION OF TEAM AND CROSS-SKILL MAINTENANCE

Team maintenance (the assignment of two or more individuals to a maintenance task) and cross-skill maintenance (the assignment of personnel trained in one skill area to a maintenance task that is associated with a different skill area) appear to be common practices, but both are intractable constraints for assessing training effectiveness. A number of reasons lie behind team maintenance. It provides a vehicle for OJT within the normal flow of shop work; some equipments are too large to be handled by one person; some maintenance tasks may require the simultaneous observation or operation of equipments at different locations (e.g., a display panel in the cockpit of an aircraft and a test set located outside the aircraft); it permits higher utilization of maintenance facilities (in particular, two- or three-shift shop operations). Team maintenance complicates assessing training effectiveness for two reasons. First, there would be no systematic way to quantify the individual contributions of team members to the completion of a single maintenance task. Second, formal school training represents only the initial stages in the development of an individual's job skills and is generally followed by OJT at the individual's duty station. As a result, the effectiveness of different methods and amounts of school training would be diluted by subsequent OJT and experience. Moreover, maintenance teams would typically be composed of individuals with differing levels of experience and/or training, and the newly trained personnel would have little impact on overall team performance.

The effectiveness of training in a given skill area can be assessed only where maintenance performance is measured in tasks in that skill area by individuals who have been trained in that skill. However, personnel may be assigned to maintenance tasks in areas other than those for which they have been trained for two reasons. Daily workloads vary among the different WCs of a maintenance organization, and cross-skill work permits personnel to be shifted to areas of high loadings to minimize bottlenecks and equipment downtimes. Cross-skill maintenance also constitutes a form of OJT to enhance maintenance organizations' adaptabilities in satisfying the higher (and perhaps more variable) workloads that would be experienced under combat conditions.

Since neither team nor cross-skill maintenance provide valid bases for assessing training effectiveness, reported maintenance data would have to identify their occurrences, so that they could be eliminated from the analyses.

A method for assessing the overall performance of organizational maintenance units was suggested in a recent study performed for the Naval Equipment Training Center.* The concept behind this approach is that some maintenance actions are not successful in correcting equipment malfunctions or result in damage to equipment. Such cases are defined as errors; three types of errors are defined, as follows:

- Equipments that, in fact, are functioning correctly are replaced;
- Equipments that, in fact, are malfunctioning are not replaced; and
- Repairs are performed that do not correct malfunctions or result in other malfunctions.

If the occurrence of these errors could be unambiguously associated with the actions of maintenance personnel they might provide a measure of performance of a maintenance unit as a whole. The AMES model is limited to assessing the impact of such errors on corrective maintenance of the organizational echelon of Naval aviation. Its applicability to assessing the effectiveness of particular training programs is discussed in the section below that addresses the Aviation 3-M system.

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*Gold, David, Bruce Kleine, Frank Fuchs, Sal Ravo, and Kay Inaba, Aircraft Maintenance Effectiveness Simulation (AMES) Model; Final Report. Technical Report NAVTRAEQUIPCEN 77-D-0028-1, Naval Training Equipment Center, Orlando, FL 23813, 1980 (draft).

TABLE 1. CHARACTERISTICS OF DATA CREATED BY MAINTENANCE MANAGEMENT SYSTEMS

Characteristics of Data	Maintenance Management System			
	TAMMS (Army)	Ships' 3-M (Navy)	Aviation 3-M (Navy)	66-1/66-5 (Air Force)
Applicable equipment	All equipment	All ships	All aircraft[a]	All equipment[b]
Extent of maintenance activity documentation	Total	Selected Types of Maintenance	Total	Total
Central reporting of recorded data	None	Total	Total	Total
Level of documentation	Maintenance Task	Maintenance Action[c]	Maintenance Task	Maintenance Task
Data describes (or answers)				
What equipment, at: Major system level	-	C	-	-
Subsystem or component level	C	-	C	C
Why maintenance was required	C	E	C	C
What was done to it	C	E	C	C
Who did it: Individual	-	-	E[d]	-
Work center (or skill-related shop)	-	C[e]	C	C
Maintenance organization (or more than one work center)	C		-	-

Note: C = Coded; E = English

[a]Includes aircraft, air-launched missiles, support equipment, training equipment.

[b]Includes aircraft; ground and air-launched missiles; precision measuring and other support equipment; training equipment; ground communications, electronics, and meteorological equipment.

[c]Group of maintenance tasks.

[d]Individuals performing maintenance are identified by name only in initial hardcopy forms that are retained by local units for a limited time.

[e]All work centers involved in a maintenance action are identified in one record.

Each of the four reporting systems is evaluated below, in summary form. Table 1 presents an overview of the characteristics of each system. Displays and discussions of the forms on which maintenance data are recorded in the four systems are presented in the Appendix.

IV. NAVAL AVIATION 3-M AND AIR FORCE 66-1/66-5 SYSTEMS

The Naval Aviation 3-M and Air Force 66-1/66-5 systems are discussed together because they provide nearly similar data. In fact, it appears as though the data structures derive from a common base. The description and evaluation found below applies to both systems, except where specific differences are noted. The discussion is phrased in terms of aircraft systems. However, other aeronautical systems (missiles, aircraft support equipment, etc.) use the same data descriptors; together, these systems account for the bulk of equipment holdings of both the Air Force and the Naval air arm.

In discussing these systems, it is useful to distinguish among three basic functions provided by maintenance organizations:

- Aircraft support services (including flight-line and flight operations services);
- Look-phase of equipment inspections;
- Corrective maintenance (including the repair of deficiencies noted during the look-phase of the inspections, the repair of malfunctions noted at other times, modifications, and non-maintenance work that supports corrective maintenance).

A. DATA REPORTED

The types of data reported by these systems provide at least a potential for assessing maintenance performance in a manner that reflects on training effectiveness. That is, the data address the questions of what equipment was maintained, what was wrong, what was done, and by whom.

1. What Equipment

The equipment on which maintenance is performed is identified through the combination of the weapon end-item and the Work Unit Code (WUC) structure defined for that end item, as required by MIL-STD 780E (AS) (Military Standard Work Unit Codes for Aeronautical Equipment). With the detail embodied in WUC structures, the end-item/WUC combination typically identifies equipment that can be associated with a narrow skill area related to specific training programs.

2. What Was Wrong

Over 200 explanations (with assigned code values) are provided to describe the nature of equipment malfunctions or other reasons for undertaking maintenance. These codes serve as an initial diagnosis to aid the maintenance process and, as possibly amended, a final explanation of the reasons for maintenance in historical records. Most of the reasons for maintenance can be loosely grouped into six categories, as follows:

- Loss, failure, deterioration, etc., of parts and components;
- Degraded performance or out-of-range tolerance of test readings of subsystems and assemblies;
- Accident or other damage;
- Maintenance and operator errors;
- No malfunction--no reason provided;

- No malfunction--assemblies/components processed for other reasons (e.g., removed for scheduled maintenance or to facilitate other maintenance).

3. What Was Done

Describing what was done in the maintenance of equipment involves two considerations: the extent of a maintenance job that is documented separately (maintenance action or maintenance task, as discussed above) and what the maintenance entailed. Two coded descriptors, Type Maintenance (TM) and Action Taken (AT), are employed to describe what, in fact, was done in the course of maintenance. (Examples of TM are general support, unscheduled maintenance, salvage, and various types of inspections; examples of AT are remove, repair, calibrate, and corrosion treatment.) Taken together, the AT and TM descriptors allow an unambiguous classification of all maintenance performed into the three major functions: support services, look-phase of inspections, and corrective maintenance. However, the amount of detail provided regarding the nature of maintenance performed varies greatly among these functions.

The distinction between "maintenance action" and "maintenance task" was presented above (maintenance action consists of a number of maintenance tasks). In these reporting systems a maintenance action is identified through the assignment of a Job Control Number (JCN). Each combination of TM and AT performed by each work center involved in a maintenance action comprises a maintenance task; all maintenance tasks are separately documented in historical records, and each task is related back to the maintenance action through the JCN.

4. By Whom

Both Air Force and Navy maintenance performed by organizational and intermediate echelons and the elements of both echelons are formed into WCs. In both reporting systems documentation of each maintenance task identifies a performing work center; however, differences between organizational and intermediate echelons in the way work centers are formed has an impact on how closely WC identification can be associated with skill area and training.

For both services, intermediate maintenance WCs are related to type of equipment maintained in a way that relates to skill and training. (Examples of intermediate-level WCs are airframe structure, jet engine, navigation system.) Organizational maintenance WCs are organized around both type of equipment (similar to the intermediate organization) and functions performed. The functionally organized centers (e.g., flight line, base flight, inspection, support equipment) are associated with support services and the look-phase of inspections, and these WCs may be manned by personnel with a variety of skills and training so that performance would be difficult to relate to particular training courses.

In the Aviation 3-M system, initial (hardcopy) documentation of corrective maintenance and the look-phase of major inspections includes names (and man-hours) of individuals performing the work. While this might provide a direct relationship between performance and training, these records are held only by the originating maintenance units and are retained for only 6 months so that their availability for analyses is limited.

B. ASSESSMENT

Even though the reported data address the proper questions for assessing training effectiveness, both the Aviation 3-M and 66-1/66-5 systems have limited capabilities in this regard. The structures of the five data codes show a heavy emphasis on corrective maintenance. (Three of the five categories are applicable only to this function, as shown in Table 2). The result is that the usefulness of these data in assessing training differs markedly among the three types of maintenance.

TABLE 2. EMPHASIS OF DATA CODES

Question	Data Code	Type of Maintenance		
		Support Services	Look-Phase of Inspections	Corrective
What equipment?	Work Unit Code (WUC)			X
What was wrong?	Malfunction Code			X
What was done?	Action Taken Code (AT)			X
	Type Maintenance Code (TM)	X	X	X
Who did it?	Work Center Code (WC)	X	X	X

1. <u>Support Services and Look-Phase of Inspections</u>

By definition, support services and the look-phase of inspections do not involve malfunctions. Both functions are typically concerned with complete end-items, so that the WUC has little meaning. The AT code is used only with corrective maintenance. Nominally, this leaves the combination of TM and the performing WC as the only way to characterize both functions, and few TM code values are defined. (Only one value of the TM code is provided to cover all support services; TM values describing inspections are limited to the type of inspection performed.)

This sketchy specification is supplemented by the use of special codes that are, in effect, extensions of and partially redundant with, the TM code. In the Aviation 3-M system, Support Action Codes (SAC) are defined which identify (1) several types of support services (e.g., operational support, corrosion control), (2) different types of maintenance support operations (e.g., shop support, engine build-up and tear-down); and (3) types of minor inspections. For major inspections, the WUC block of the maintenance report form is used with a special code to identify the type of inspection performed. In the 66-1/66-5 system a Support General code structure is defined, and its values are inserted in the WUC block of the reporting form to identify the type of support service provided or inspection performed (similar to the SAC and special use of the WUC block in the 3-M system).

In fact, a number of different tasks are involved in support services while the look-phase of some types of inspections are extensive undertakings. In both cases, a range of skills (and training) may be involved. While the data code values available may be adequate for managing these functions, they seem wholly insufficient to characterize the different tasks in a way that identifies the skills employed, a necessary condition for assessing training effectiveness.

It might be argued that some measure of maintenance performance could be obtained from the combination of TM (as supplemented by the SAC and special use of the WUC block) and identification of work centers or individuals. Since both appear to involve standardized tasks that are essentially unchanged between different organizations maintaining the same equipment end-items, an essential ingredient for comparability is present.

However, it does not appear valid to relate performance measured in this way to training effectiveness. Support services and minor inspections are provided by organizational echelon WCs that specialize in these functions. For maintenance managed within the Aviation 3-M and 66-1 systems neither function represents a skill area associated with a particular type of equipment (such as avionics or engines) that can be identified with particular training programs, and one might expect to find such WCs populated with individuals from a variety of training backgrounds. Within the 66-5 management system these functions are performed by personnel specifically trained in support services as well as personnel trained in specific technical skill areas. With respect to major inspections, the inspection WCs may be assisted by personnel from repair WCs (either organization or intermediate echelon) that can be associated with specific skill areas and training. This is necessarily team maintenance, and there appears to be no way to separate the contributions of different individuals or work centers to the overall effort.

Assessing training effectiveness in this manner would require a large sample of similarly described maintenance tasks across organizations (maintaining the same type of equipment) that could be differentiated solely on the basis of training received. Even with large samples, inferences relating performance to training effectiveness would be weak. Both service and inspection look-phases are predominantly team efforts where the impact of newly trained individuals on overall performance would be diluted by the supervision and abilities of experienced personnel. A further consideration in drawing conclusions is that the skills involved in support service and inspections may be relatively small and unrepresentative of the range of skills for which individuals are trained.

2. Corrective Maintenance

At first appearance this is the more promising area for determining maintenance performance in a way that reflects on training effectiveness. The types of maintenance reported include, essentially, the full range of skills for which people are trained; the full range of data codes are available for describing both the nature of maintenance and who performed it. If it is accepted that the combination of repair WC and work unit code adequately describes skill areas that can be related to training programs, then the TM, AT, and malfunction codes are available to identify what a maintenance task involves in terms of skill and effort.

In the Aviation 3-M system, approximately 200 malfunction codes are defined; twelve TM codes and 22 AT codes (including 10 that provide reasons why no action was taken) are applicable. These values allow a set of close to 30,000* unique combinations of the three descriptors for a given WUC and the set will vary among major systems of a weapon end-item. In the 66-1/66-5 systems something on the order of 50,000 combinations appear possible; they define roughly 20 percent more malfunction, 10 percent more action taken, and 30 percent more-type maintenance descriptors than Aviation 3-M.

This large number of combinations presents its own problem. One must consider whether the systems are too complex to allow reliable groupings and separations of similar and different maintenance tasks. There is no doubt that the number of potential combinations can be significantly reduced and still permit one to identify similar maintenance tasks. Roughly one-half of the malfunction codes are applicable to each major system (denoted by the first two digits of the WUC), e.g., less than 90 values are applicable to landing gear systems. Some combinations of malfunction, TM, and AT codes are indicative of the same maintenance task, e.g., it is irrelevant whether a repair is made as unscheduled maintenance or as the fix phase of an inspection. Even if 90 percent could be eliminated on such grounds, there remain a large number of combinations to be interpreted, especially when their full meanings might differ as a function of other data contained in the maintenance records. For example, the skills required to troubleshoot a particular model of electronic equipment with the same apparent (or stated) malfunction may be quite different between organizational and intermediate echelon maintenance. At the same time, one must consider whether the number of logical combinations of codes that are available within the systems is sufficient to distinguish among all the different maintenance requirements on such

*200 x 12 x (22 - 9).

complex equipments as military aircraft. Both questions are crucial in assessing the reporting systems, but we can offer no definitive answers.

There are, no doubt, a number of standardized and repetitively performed maintenance tasks that can be unambiguously identified from the values given to one (or more) of the three data codes and thereby serve as indicators of maintenance performance in studies of training effectiveness. For example, removing or installing a particular piece of equipment on a given end-item (an action taken) requires the same skills, regardless of why the removal or installation was required, i.e., regardless of malfunction or TM involved. Limiting assessment to such cases, however, amounts to evaluation by exception and raises again the question of whether the set of tasks that can be identified in this manner is representative of the range of skills addressed by training programs.

In fact, the assumption that the combination of WUC and WC adequately define skill areas and training may not be valid for reasons that have to do with unit operational requirements (rather than the nature of reporting systems). Maintenance in the Tactical Air Forces (TAC, PACAF, AAC, USAFE) is managed through the 66-5 system (referred to as Production-Oriented Maintenance Organization, or POMO). Maintenance squadrons are planned to be deployed with flight squadrons (in the event of mobilization) and are structured with the objective of sustaining high levels of operations (sortie generation) in the deployed condition. Such operating levels should require a significant amount of cross-skill maintenance; combat readiness in these organizations would require cross-skill maintenance to be employed during non-deployed periods. This appears to be accomplished in two ways, (1) by forming permanent repair teams composed of individuals with diverse skill and training backgrounds and attaching these teams to a single WC and (2) by assigning repair teams or individuals from one skill area to maintenance tasks controlled by WCs associated with other skills. For SAC and MAC units, whose maintenance is managed through the 66-1 system and with the Navy maintenance squadron organization, cross-skill maintenance may occur to varying extents as the result of differences in local command policies and variations in workloads.

In any case, a consistent relationship between WC, WUC, and skill area in reported maintenance data cannot be established, and this weakens the argument for using maintenance data to determine training effectiveness. To establish such a relationship, data would have to identify where (on what individual maintenance tasks) cross-skill work occurs, so that these cases could be eliminated from the sampling process; it is uncertain that this is possible.

Team maintenance introduces a further complication in inferring training effectiveness. It appears to be a common, if not prevalent, practice, especially in Air Force units where recent trainees must undergo some period of OJT and be expressly qualified before they can perform independent work. Air Force reporting notes the occurrence of team maintenance so that, at the least, its extent can be known, and it may be possible to characterize the types of maintenance tasks that are typically performed by a single individual. In the Aviation 3-M system, only the initial hardcopy records make any note of the numbers of persons responsible for a maintenance task so it would be impossible to determine either the extent or occurrences of team maintenance from the ADP files that contain the bulk of historical data.

3. Maintenance Errors

Gold, et al.* define three types of maintenance errors and cite the following Aviation 3-M data as evidence of their occurrence.

Error	Evidence
1. Replacing equipments that are functioning correctly.	Equipment removed at organizational maintenance shows no defects when it is bench-checked at intermediate maintenance. (One malfunction code identifies no-defect items.)
2. Not replacing equipments that are malfunctioning.	Successive flights of one aircraft are accompanied by corrective maintenance actions on the same aircraft system, and these actions suddenly stop. That is, the final corrective action was successful. Analysis of the documentation of the series of corrective actions will determine whether the repetitive failures resulted from error or other causes.

*Gold et al., Aircraft Maintenance Effectiveness Simulation (AMES) Model: Final Report, Technical Report NAVTRAEQUIPCEN 77-D-0028-1, Naval Training Equipment Center, Orlando, FL 32813 (1980).

3. Repairs do not correct malfunctions or result in other malfunctions. — The occurrence of 15 malfunction codes in 3-M records is evidence of either definite errors or probable errors. For those codes that are classed as probable errors, analysis of prior maintenance actions will determine whether the malfunction resulted from error or other causes.

The impact of errors at the organizational level was estimated by applying one year's worth of 3-M records for six Navy aircraft squadrons to the AMES model. The simulation concluded that, with a 90 percent reduction in error rates, the same number of missions could be flown with one fewer aircraft per squadron of 12 aircraft. Numbers of missions flown is only one of several simultaneous measures of unit performance among which trade-offs can be made (e.g., maintenance man-hours per flying hour, operational readiness, cannibalization rates), and no other measures were addressed in the simulation.

Since evidence of maintenance errors is found in the Aviation 3-M records, the data are capable of characterizing the tasks on which they occur (i.e., the equipment involved, what was wrong with it, what was done to it, and by whom). Further, with the similarities in data developed in the Aviation 3-M and 66-1/66-5 systems, each should be equally capable of relating errors to training effectiveness. However, there are several considerations beyond the data reported that must be addressed before a relationship between these errors and training effectiveness can be established, as follows:

- Whether the three events that are classified as errors do, in fact, constitute errors, and, if so, whether they can unambiguously be associated with the maintenance function;

- Whether these events occur with sufficient frequency across the range of aviation equipments and skill areas for which personnel are trained; and
- Whether the tasks on which they occur (in an individual skill area) are representative of the range of tasks for which personnel are trained in that skill.

The concept of error and the 3-M data cited as evidence have been reviewed with personnel from the Naval Air Systems Command (NAVAIR) and the Deputy Chief of Naval Operations (DCNO) for Air Warfare that are experienced in both aircraft maintenance and the Aviation 3-M system. In all cases, these individuals stated that replacements of operating equipment, failure to replace malfunctioning equipment, and most of the 15 particular malfunction codes can be consistent with efficient unit operations (i.e., they are not necessarily errors). They further stated that whether or not these events are considered as errors, other aspects of military operations may be as or more important than maintenance as reasons for their occurrence. The other aspects that were cited include the complexity and reliability of equipment, the adequacy of the support equipment and documentation provided organizational maintenance personnel, the competance of equipment operating personnel, unit operating environments, and command decisions.

A frequently cited example was that the support equipment and documentation for complex avionics systems provided to organizational maintenance are frequently incapable of isolating malfunctions to a single black box within the system. If squadron policy is to replace and bench-check one box at a time, an incorrect first guess as to which box to replace will result in two "errors" -- replacing functioning equipment and not replacing malfunctioning equipment; if squadron policy is to replace the total system, the result will be the replacement of a series of functioning equipments. Deficiencies of support equipment and documentation might be considered as a maintenance system inefficiency, but it is not a valid reflection of the capabilities of maintenance personnel. In addition, it may be that the cost of providing organizational maintenance units with test equipment that would resolve all such ambiguities is higher than the cost of the erroneous equipment replacements.

The impacts of these other facets of unit operations may be systematic between different squadrons operating the same equipments so that the frequency of occurrence of errors will not provide a valid basis for comparison, e.g., carrier- versus land-basing, carrier-based and operating in different theatres, and different squadron command practices. Verifying that such purported errors are, in fact, errors, isolating their causes (e.g., maintenance, test procedures, operating environment), and establishing comparability among different units appears to involve extensive data and analysis, possibly including material not currently reported through Aviation 3-M. Considering the size of the Naval air arm, it might prove difficult or impossible to gather a sufficiently large sample to identify, with confidence, true errors that can be attributed to maintenance personnel, even if the impacts of other aspects of unit operations were not systematic.

Further complications in assessing training effectiveness through analysis of errors lie in whether the events that can be verified as errors occur across the range of different aircraft equipments (and associated skill-areas) and, for a given type of equipment, whether the types of tasks on which they occur are representative of the job requirements of the associated skill-areas. Some types of equipments are difficult to replace because of size or structural integration (e.g., engines and flight control systems) while other types are compatible with and designed for easy replacement (e.g., avionics).

Efficient maintenance practice would dictate that a disproportionate share of off-equipment maintenance would occur in areas such as avionics so that these would be the skill-areas where errors involving removals would be concentrated. NAVAIR has previously studied faulty removals of equipment and found that 90 percent occur in avionic systems. This leaves little ground for commission of this type of error in other systems and casts doubt upon the capability of error analysis for assessing training effectiveness across a range of skill areas. On-equipment maintenance and equipment replacement is concentrated at the organizational echelon so that all errors involving removals of equipment would occur at this level, but training programs are not necessarily limited to organizational maintenance tasks. Further, it cannot be assumed that the malfunctions that result in equipment replacement (as distinct from those that result in on-equipment corrections) utilize the range of skills in which organizational maintenance personnel are trained.

The arguments and examples above address only the two classes of "errors" that involve replacements of equipment. However, the discussions suggested that similar arguments would apply to the 15 specified malfunction codes. Each of the discussants singled out a few of the 15 codes as being "primarily" maintenance induced, but there was little agreement concerning which of the 15 fell into this category. In addition, they typically offered other primary causes for a number of remaining codes, implied that individual codes would be primarily associated with a limited number of aircraft system types, and that the main underlying causes (support equipment, operational environment, maintenance) lying behind particular codes may differ according to the type of aircraft system. When all the arguments are considered, it appears highly unlikely that the type of analysis proposed by AMES would shed light on the relative effectiveness of training programs.

4. Conclusion

The basic problem in assessing training effectiveness in the field may lie in the complexity of military equipment and organization. Aviation 3-M and 66-1/66-5 are large and complex systems that are concerned with management and control of maintenance at the unit level. Design and implementation of a data system that would satisfy the management function and also provide assessments of the performance and training of individuals does not seem feasible. Assessing the effectiveness of maintenance training would appear to require a separate data collection and processing system. However, with current organizational practices (e.g., cross-skill and team maintenance) it is hard to see how a data system specifically addressed to the performance of maintenance personnel could generate adequate information regarding training effectiveness from day-to-day operations of maintenance units.

This rather discouraging picture has been confirmed informally by discussions with personnel in NAVAIR and the Air Force Deputy Chief of Staff for Logistics. Their view is that these systems cannot answer questions regarding training effectiveness. In fact, NAVAIR currently commits resources to determining unit effectiveness by further analysis of 3-M-generated records--the NAMP Improvement Program (NIP). In this case, unit performance is evaluated through ADP in terms of gross criteria, such as operational readiness and cannibalization rates; assessing reasons for the observed performance and prescriptions for improvement require direct contact (such as field visits) with the units evaluated. At that, the approach is more straightforward and assessment criteria are certainly more visible than would be the case in evaluating the performance of individuals trained in one of the numerous skills required in a maintenance organization.

V. SHIPS' 3-M

Naval ship maintenance is managed through the Ships' Maintenance and Material Management (Ships' 3-M) System. Ships, their outfitting, and their operation display features not found in other weapon systems that affect the way maintenance is performed and both the extent and format of reported maintenance data.

Ships of the same class (including those launched within the same time period) generally display configuration differences, especially with regard to the smaller assemblies and components comprising major functional systems. For example, while the use of particular models of the major elements of a ship's main propulsion system (boiler, turbine, etc.) may be a design specification, ship builders are free to use alternative models of valves and pumps so long as they are compatible with the major elements of the system. The models installed initially may vary between ships produced under the same contract, and the initial outfitting may be replaced by different models during ships' lifespans. Such variations complicate problems in configuration control and stockage of repair parts.

Ships are capable of long periods of independent operations where a ship's force (crew) provides the only source of maintenance of the ship's material condition. However, ships are not outfitted or manned to be capable of maintaining full operational capabilities, in all assigned missions, at all times. Ship operations, lack of repair part stocks, and the unpredictable occurrence of equipment breakdowns may require that some maintenance be deferred for later correction by ship's force; the ship incurs degraded capabilities during these time periods. In addition, ships are not outfitted or manned to be wholly self-sufficient in terms of maintenance. Some equipment repairs may require facilities, tools, and documentation not available to the ship's force or be beyond their skills. In these cases, maintenance must be deferred until the ship is provided an "availability" at an Intermediate Maintenance Activity (IMA)--a tender or shipyard.

Maintenance documentation under Ships' 3-M reflects the shipboard environment and higher-command responsibilities for tracking and control of fleet readiness and ship configurations and the management of IMA workloads. As a general rule (subject to two exceptions noted below), reporting of maintenance is required only where changes in ship configurations result and where deferral periods exceed 30 days. (The 30-day period applies to both preventive and corrective maintenance.) The two exceptions are that all corrective maintenance on submarines is reported and all maintenance on equipments placed on the Selected Equipment List (SEL) is reported. (The SEL consists of roughly 500 equipments with histories of maintenance problems or equipments that are new or modified and for which maintenance profiles and parts stockage requirements have not been developed.)

A. DATA REPORTED

1. What Equipment

The form in which data are reported in ships' 3-M does not answer the basic questions of What equipment? What was wrong with it? What was done to it? and By whom? in a manner that sheds light on maintenance performance or training effectiveness. Equipment undergoing maintenance is identified through two systems: the Equipment Identification Code (EIC) and the Allowance Parts List (APL). The EIC is structured to identify functions performed by equipment. In a four-character code, the first character denotes major functional areas (e.g., electric power generation, main propulsion), and the other three characters identify functions performed with the major areas (e.g., power generation control group or system, main propulsion gas turbine.) A single EIC value typically includes a conglomerate of smaller equipments (such as all the meters and controls associated with a control panel) which may malfunction and require maintenance. Except in the areas of electronic and ordnance equipment, a single EIC code value refers strictly to the function performed and may encompass a large number of equipment configurations (equipment models and manufacturers). For electronic and ordnance equipment, a single EIC value refers to both the function performed and the specific configuration of an equipment end-item (in terms of standard AN and Mk/Mod number designations). In neither case, though, is the EIC structured to identify components of the end-item (such as power supplies, displays). That is, the EIC value references the complete system and not the elements of the system that, in fact, fail and undergo maintenance.

The APL is a technical document used in equipment maintenance and ship configuration control. One APL refers to a particular model of an end-item or major assembly produced by a single manufacturer and associated with a unique parts list. A number of APLs may be associated with a single EIC value since a number of end-item models may provide a particular function and because a number of manufacturers may produce a single end-item model. One section of an APL consists of a parts list (to the bit and piece level) in terms of national stock number and manufacturer's part number. Like the EIC system, APLs typically provide identification only to the system or major assembly level.

2. What Was Wrong and What Was Done

The nature of equipment malfunctions and actions taken to correct them are described only in natural language and without any defined set of keywords. While this allows great flexibility of description, it leaves no way by which similarity or comparability among maintenance actions can be established. Comparability is further complicated by the formation of only one maintenance record for reporting a complete maintenance action, rather than well-defined individual (and repetitive) tasks that are a part of numerous maintenance actions. Given the extent and complexity of maintenance actions, it could well be that no two are, in fact, sufficiently similar to provide a basis for comparison.

3. By Whom

The identification of who performs maintenance provides little in the way of useful information for assessing training effectiveness, although report forms may identify both individuals and WCs. Individuals are named as contact points rather than as those, in fact, performing the maintenance. More than one WC may be involved in the completion of maintenance, and there is no way to separate the contributions of (or tasks performed by) the different centers. Further, when maintenance is deferred, it is frequently because the facilities, skills, and/or materials required are available only at IMAs. In these cases, the completion of maintenance will generally involve personnel from both the ship undergoing repair and the IMA.

B. Assessment

The Ships' 3-M system appears to offer no potential for assessing maintenance performance of individuals. Reasons for this negative conclusion lie in considerations as basic as the nature of shipboard equipment and ship operations rather than simply features of the reporting system itself.

Regardless of the form or extent of maintenance reporting, the lack of standardization of ship outfitting is a sufficient reason to conclude that relationships cannot easily be established between the reported data and the capabilities of maintenance personnel (and, hence, training effectiveness). While ships of the same class may be outfitted to the same mission capabilities, the systems by which those capabilities are attained, their assemblies and components, and their on-board locations may differ. These differences exist at the time of initial ship acceptance and increase with age as ships undergo overhaul, modernization, and other configuration changes. Seemingly minor differences in equipment (e.g., substitute models of valves used in high-pressure steam lines) and location of the same equipment (e.g., engine room or upper deck location of a particular configuration of air-compressing and drying equipment) may have significant impacts on equipment performance and maintainability. While these impacts will be reflected in the reported maintenance data, they cannot be taken as indicators of the capabilities of maintenance personnel or of training effectiveness. Even though ships' equipment configurations might be exactly known, they may be sufficiently different that adequate samples of comparable maintenance actions could not be gathered.

A further complication involves ship overhaul periods. Frequency of equipment breakdown appears to increase as a function of the time since last overhaul, and there are reasons to assume that the amount of effort to effect repair will vary in a similar fashion. At any given time, there will be a distribution of times since overhaul among ships of the fleet, and this should be reflected in reported maintenance data. To the extent that time since overhaul does have an impact on maintenance performance criteria (e.g., breakdown rates, man-hours to repair) it will mask the effect of training effectiveness on performance.

A most telling shortcoming of the management system is its incomplete documentation. Both preventive and corrective maintenance should be completed without deferral whenever possible. Even though it is not possible to quantify the fraction of maintenance effort reported, it seems probable that the major portion of surface ship maintenance will not be deferred and, hence, not reported, and that a significant portion of submarine maintenance will consist of non-deferred preventive maintenance that also will not be reported. In addition, it can be assumed that there are innate differences between tasks that are deferred and those that are not. As a result, it cannot be assumed that the skills required for that maintenance which is reported will comprise a representative sample of the range of skills for which personnel are trained.

A second major shortcoming of the system is that the individual historical records that are developed encompass all efforts associated with a complete maintenance action. Maintenance actions are large-scale efforts compared with individual maintenance tasks (that form the individual records by which aircraft maintenance is reported). The larger the scope of effort the smaller the chance that maintenance undertakings will, in fact, be comparable. Indeed, if each maintenance action is unique in some way there will be little or no grounds for comparative analysis. (This statement might hold true even if all maintenance were reported and if ships and their outfitting were wholly standardized.) In addition, when one considers that descriptions of what is wrong with equipment and what is done to repair it can be provided only in English phrases, the probability of correctly sorting reported maintenance into sets of comparable undertakings appears remote.

Further, such large-scale undertakings would likely involve personnel with a variety of skills (and training backgrounds) from several WCs. Where maintenance is completed with IMA assistance personnel from at least two WCs would be involved--one from the tended ship and one from the IMA. At completion, man-hours will necessarily have been expended by both ship's force and IMA personnel. It would appear that the mix of training, experience, skill levels, etc. embodied in the man-hours expended in each maintenance action may be unique and too complex to provide a basis for distinguishing among maintenance actions on the basis of training alone.

Beyond the problems that can be laid to the nature of ships themselves (e.g., lack of standard configurations) and the basic features of this management system (i.e., some maintenance is not documented and the remainder is documented only in terms of maintenance actions), the form in which data are reported does not adequately answer the four questions basic to assessing performance and training effectiveness. The equipment identification systems (EIC and APL) do not provide adequate answers to what equipment is maintained. For other than electronic and ordnance equipments, an EIC may reference a variety of configurations with widely differing maintenance characteristics. While the EIC system for electronic and ordnance equipments and the APL system identify precise configurations, they typically do so only at a system level. This provides no way to isolate the individual assemblies and components that, in fact, fail and require maintenance, and the type and level of skills required to repair different components of the same system may vary widely.

VI. THE ARMY MAINTENANCE MANAGEMENT SYSTEM (TAMMS) AND THE SAMPLE DATA COLLECTION PROGRAM

Maintenance of Army equipment is managed through TAMMS. There is a noticeable similarity among TAMMS, the Naval Aviation 3-M, and the Air Force 66-1/66-5 systems in the way that maintenance tasks are documented. TAMMS documents all maintenance performed, and information is recorded on the basis of individual maintenance tasks. Reasons why maintenance was required and what it entailed are provided through code structures that are quite similar to the malfunction and the AT and TM codes of Aviation 3-M and 66-1/66-5. TAMMS does, however, differ in two important ways from both Aviation 3-M and 66-1/66-5 as well as the Ships' 3-M system. The first is that its records identify neither skill-related WCs nor individuals performing maintenance. The second is that, except for equipment modifications and warranty claims, the maintenance data are recorded at the local level but are not transcribed for ADP and are not reported to higher echelons or a service-wide data repository. The only centralized reporting of comparable data occurs through the Sample Data Collection (SDC) Program, discussed later, which is not a part of TAMMS.

A. DATA RECORDED

Within TAMMS, equipment is identified through the National Stock Number (NSN) system and, for aircraft and missiles, by a Component Breakdown (CB) code that provides a subsystem identification similar to the first one or two digits of WUC structures, as defined in MIL-STD-780E. NSN is the basic cataloging system through which equipment and material are identified by all services. NSNs refer to unique configurations of equipments (end-items, major systems, subsystems, and assemblies) and to piece-parts and components with unique characteristics. While it provides a precise (though possibly cumbersome) specification of individual material items, it does not, by itself, always provide an unambiguous identification of the equipment upon which maintenance is performed.

Malfunctions are described by a set of Failure Codes. For aeronautical equipment, roughly 200 code values are defined that, for the most part, are the same as those employed by Aviation 3-M and 66-1/66-5. For non-aeronautical equipment, less than 30 values are defined, and these are dominated by malfunctions that are typically associated with automotive equipment.

What was done in the performance of maintenance of equipment is described by a set of Action Codes that serve the same function as the combination of codes employed by Aviation 3-M and 66-1/66-5 (i.e., the Action Taken and Type Maintenance codes, the Support Action Code in 3-M and the Support General code in 66-1/66-5).

Identification of who performs maintenance is limited to the naming of maintenance organizations (typically company units). Other than depot, Army Maintenance is structured into organizational and intermediate echelons (with two intermediate echelons organized for ground-equipment maintenance). Intermediate maintenance and aircraft and missile organizational maintenance are organized into companies and platoons that are further structured into a small number of "sections" that can be associated with broad skill areas (e.g., electronics, automotive). Other organizational echelon units typically contain a single maintenance section that is responsible for all equipment belonging to that unit. In neither case does separation of skill areas approach that found in Naval or Air Force WCs. It should also be noted that while all companies and platoons are organized into sections according to function performed (e.g., maintenance, supply), the Army management system provides no way to identify or distinguish among different sections.

Organizational maintenance units in the Army are sufficiently small so that a WC structure does not appear necessary or useful to manage daily operations. The responsibilities of maintenance sections may encompass a range of skill areas, while the small manning levels frequently permit assignment of only one or two individuals with appropriate Military Occupational Specialties (MOS) to a number of these areas. It would be unlikely that the flow of tasks could be matched with available man-hours, by MOS, in a way that would avoid frequent assignments of individuals to tasks outside of their MOSs. Further, according to Army personnel, under combat conditions a significant fraction of organizational maintenance would be initiated by the dispatch of individuals or small teams to the sites of disabled equipments on the basis of sketchy descriptions of the nature of malfunctions. The uncertainties regarding what is wrong would make it unlikely that personnel could be dispatched on the basis of skill area. Under these conditions, a work center structure would be of little value and might introduce an element of inflexibility.

B. ASSESSMENT

TAMMS, as currently implemented, provides a negligible capability for assessing training effectiveness. This negative assessment rests on three features of the system: the absence of central reporting, the nature of data that are recorded, and the nature and organization of maintenance in the Army.

1. Data Reporting

Suprisingly, the absence of central data reporting appears to be the lesser problem of the three noted above. Currently, records are compiled on all maintenance activity and retained by local units for 90 days. All records older than this appear to be irretrievable; however, central reporting could be initiated at any time through a requirement to submit the current hard copy records to a central collection point--as is currently done under the SDC programs. Although expensive and unattractive, manual data extraction and analysis are possible. Further, a portion of currently recorded data (that pertaining to equipment modifications and warranty claims) is centrally reported and processed through ADP. The capability represented by this reporting might provide a basis for expanding TAMMS into a general reporting system.

2. Recorded Data

There appear to be some inadequacies in the data recorded for answering the four basic questions concerning maintenance performed. While the NSN system provides an unambiguous identity of individual equipment and parts, it is not wholly satisfactory for assessing performance. First, it is cumbersome to use and quite susceptible to transcription errors; an NSN consists of 13 numeric digits of which only the first four denote the type of equipment. Second, there is a possibility of ambiguities in the case of on-equipment maintenance; here, NSNs identify the major system or weapon end-item on which maintenance is required, the component or piece-part at fault, but not the subsystem containing the part. Should different subsystems of an end-item contain the same component, identity of the subsystem undergoing maintenance could not be established without other information. The CB code obviates this problem for aircraft and missiles, but it is not possible to assess how frequently such ambiguities would arise in the case of other, generally simpler, equipment.

Concerning what was done in performing maintenance, the use of a single code avoids the redundancy found in both Aviation

3-M and 66-1/66-5 and the values defined permit maintenance to be classified according to major function (service, look-phase of inspections, and corrective). As with Aviation 3-M and 66-1/66-5, few code values in TAMMS are available for describing services and inspections. The values that are defined for corrective maintenance in TAMMS do not allow as fine a distinction among the different maintenance tasks that may comprise a maintenance action as do those of Aviation 3-M and 66-1/66-5. In particular, the single Action Code "repair" appears to include on- and off-equipment repair, repair and replacement of attaching and auxiliary parts, assembly and disassembly of removed equipment, troubleshooting, calibration, cleaning and corrosion repair--all of which may be separately identified in 66-1/66-5. These different aspects of repairing equipment may embody quite different levels of skill and effort that could not be differentiated by TAMMS data.

3. Organization of Maintenance

A particular problem in using TAMMS data to assess Army training effectiveness is that it is not possible to relate particular maintenance tasks to individuals or skill areas in a way that can be associated with training programs. The basic problem appears to lie in Army organization and operating environments rather than in features of TAMMS data recording.

a. Organizational Maintenance. Organizational maintenance is performed predominantly at the company level and accounts for roughly one-half of maintenance MOS billets. Companies are organized into sections that can be associated with particular functions, such as operation of equipment and maintenance of equipment (among others), but there is no standard designation system for distinguishing between different types of sections. Personnel with MOSs in maintenance may be assigned to both equipment operating and maintenance sections. Where this occurs, responsibility for maintenance is split between the sections.

In equipment-operating sections, minor maintenance and service tasks may be conducted by individuals with MOSs in equipment operations. This, along with the absence of WCs in maintenance sections, results in an inseparable mix of sections and training backgrounds performing maintenance that appears to preclude relating maintenance performance to training.

Even if (1) all organizational maintenance were performed by maintenance sections that were organized by WC, (2) the sections and WC could be specifically identified in maintenance documentation, and (3) all maintenance were performed by persons with maintenance MOSs, it would still be difficult to relate performance and training effectiveness. Except for aircraft and missile units, a single maintenance section is typically unspecialized and is responsible for all equipments held by a company or the battalion to which it belongs. Companies and battalions may hold a variety of equipment whose maintenance is associated with diverse skill areas (e.g., wheeled and tracked automotive equipment, electronic equipment, armaments). However, maintenance sections are relatively small (averaging less than 20 persons), and it would appear difficult to attain either high levels of operational readiness in peacetime or high equipment utilization under combat conditions if personnel were assigned to work only in their own specialities. As a result, cross-skill maintenance should be a prevalent practice, with the implications it carries for assessing training effectiveness.

b. Intermediate Maintenance. Intermediate maintenance of ground equipment is the responsibility of two maintenance echelons. The lower, direct support (DS), is performed by units that are attached or organic to large combat units (e.g., divisions). The higher echelon is general support (GS) and is performed by units that are associated with higher commands such as corps and theatre forces. A single echelon performs intermediate maintenance of aircraft.

The problems faced in determining training effectiveness for DS maintenance of ground equipment and for intermediate maintenance in aircraft units are generally similar to those encountered in organizational maintenance. Intermediate maintenance is performed by battalions and companies that are structured into sections associated with a limited number of commodity areas (e.g., aircraft, components, and armaments for aircraft units and automotive, electrical, and engineer equipment for ground untis). Organizing sections by commodity line allows for a greater specialization of both personnel assigned and equipment maintained. However, a significant amount of cross-skill maintenance seems required because of the small size of sections (typically 20 to 25), the limited number of sections organized (typically 5 to 10), and the diversity of equipment maintained by a DS company. For example, the maintenance battalion of an armor division "support command" contains 27 hands-on maintenance sections with an average complement of 25 personnel and encompasses eight commodity areas; the largest electronic equipment maintenance section, with a complement of 28 personnel, encompasses repair of surveillance and weapons support radars, radios, telephone systems, teletypewriters, fire control system components, electronic instruments, and special electronic devices. Only one person with a corresponding MOS is authorized for half of these types of equipment.

GS maintenance is conducted by larger organizations whose sections are structured into a larger number of commodity lines where individuals can be expected to work only within their MOS areas, including more narrow specialties within individual MOSs. For example, under the "material center" organization, the GS maintenance support of an Army corps consists of four centers with approximately 1100 hands-on maintenance personnel organized into 38 sections that encompass 23 commodity lines and three commodity-independent craft areas. However, GS organizations account for no more than 20 percent of Army maintenance authorizations at combat manning levels; during peacetime periods, a significant portion of assigned personnel are normally civilian employees. Their function is to perform maintenance that is beyond the capabilities and authorizations of lower echelon units by virtue of their more extensive facilities and the greater specialization of personnel that large size permits. Even though GS organizations might be structured in a manner that permits maintenance performance to be assessed in a manner relatable to training effectiveness, the types of tasks performed could not be assumed to be representative of the skills employed at lower echelons and addressed by training courses.

c. Operating Environment. Team maintenance also appears to be a complication in assessing training effectiveness in the Army. The size of a significant fraction of ground equipment is a sufficient reason to expect extensive team maintenance among members of a maintenance section. In addition, the environment of combat conditions is a sufficient reason to expect a different kind of team maintenance (i.e., where teams are comprised of individuals from different organizational sections and echelons). Sustaining high levels of equipment availability places a premium on minimizing the extent to which equipment must be evacuated for repair. Authorizing maintenance personnel to different echelons and to different command levels and units of the lower echelon permits a flexibility in dispatching personnel to effect repairs with a minimum evacuation of disabled equipment.

The premium placed on repairs in the field during combat requires that personnel be trained in maintaining equipment under a variety of conditions (e.g., location, adequacy of repair facilities). This proficiency must be developed in peacetime and implies that maintenance will be performed under conditions ranging from fully equipped shops to improvised field settings with a minimum of tools. Where maintenance environments differ in this manner, observed variations in the times required to perform otherwise comparable maintenance operations cannot be taken as an indication of differences in proficiency or training effectiveness.

Similar examples can be found throughout the organizational structure. "Headquarters and Headquarters Companies" (HHC) of battalions typically contain maintenance sections that are responsible for the maintenance or HHC equipment and to assist the maintenance and operating sections of the battalion's companies. DS organizations contain forward support companies, attached to brigade headquarters, that are geographically close to forward areas where disabled equipment would be concentrated. The rear elements of DS units and GS organizations contain mobile teams to be dispatched for forward areas to assist both the DS forward support companies and organizational maintenance units. To be effective under combat conditions such arrangements would have to be exercised during non-combat periods, e.g., as a normal mode of operation or during field exercises and maneuvers, and would necessarily be reflected in maintenance reporting.

C. SAMPLE DATA COLLECTION

Sample Data Collection (SDC) is specifically directed to the evaluation of equipment reliability/maintainability and operation/support costs. It is implemented as a series of individual programs, of limited durations, for reporting maintenance data on specifically designated equipment using standard or modified TAMMS forms or specially designed forms.

SDC programs address specific questions, and reporting forms among them may differ to reflect their diverse interests. Where modified TAMMS or specifically designed forms are employed, it can be assumed that they will entail more extensive and detailed data than the standard TAMMS format. However, it cannot be assumed that all TAMMS data items or all data necessary for assessing performance of maintenance personnel would be relevant to and reported by all SDC programs. As a result, generalizations cannot be made regarding whether reported data satisfactorily identify the equipment subsystems and components that malfunction; the nature of malfunctions; and the tasks, man-hours, and individuals or organizations involved in their correction. Further, data reduction and evaluation procedures may have to be tailored for each SDC program.

The volume of data reported through SDC is small relative to that recorded through TAMMS, and the extent of maintenance effort that SDC data represent is similarly small relative to total maintenance resources. The life of individual SDC programs uniformly spans 1 year and can be extended only by explicit 1-year renewals. Roughly 10 SDC programs are active at one time. The scope of a program is limited to corrective maintenance on one or a few models of a single type of equipment, and data are reported on a small fraction of total inventory of that equipment. As examples, during 1979 nine SDC programs were in effect involving four models of artillery, five models of automotive equipment, one missile system, one command/control system, and nine model/designation/series (MDS) of aircraft. In the single program concerned wlth the nine aircraft models, data collection was limited to 320 aircraft held by 13 units at five U.S. bases--less than 5 percent of the Army-wide inventory of the nine MDS. Other SDC programs are comparably small.

While these small samples may be sufficient to establish maintenance and operating cost characteristics of equipment, they appear wholly inadequate for assessing performance of maintenance personnel. However, the SDC concept may provide a foundation for special data-collection programs for assessing maintenance personnel performance and training effectiveness.

VII. SUMMARY AND CONCLUSIONS

Training effectiveness is currently measured only by student achievement at school. However, the ultimate effectiveness of training is determined by the performance of personnel on-the-job; therefore, the comparative effectiveness of different amounts and methods of training should be measured by comparing on-the-job performance of personnel trained in different ways. The military services currently employ large maintenance management systems that generate extensive historical data files. If these data could be used to shed light on the performance of either maintenance organizations or the individuals assigned to them, and if the organizations or individuals can be associated with different amounts and methods of training, then these data might also shed light on the effectiveness of the training alternatives.

Five maintenance management systems were investigated: The Army Maintenance Management System (TAMMS), the Navy Ships' Material Maintenance Management (Ships' 3-M) system, the Navy Aviation Material Maintenance Management (Aviation 3-M) system, and the Air Force 66-1 and 66-5 systems. Taken together, these systems encompass organizational and intermediate maintenance of all military aircraft, all Army and Air Force ground equipment (including missiles), and all Navy ships and shipboard equipment (except nuclear missiles).

We should not be surprised to find that none of the systems, at least in their present forms, provides a suitable vehicle for assessing training effectiveness. The reasons for this conclusion lie in two different, but related, types of considerations. The first encompasses rather severe restrictions on the way maintenance must be documented if maintenance performance is to be translatable into training effectiveness. The second concerns ways in which characteristics of current military operations, maintenance practices, and equipment may be inconsistent with assessing training effectiveness. It should be noted, however, that each of these systems was designed to manage maintenance operations and were not meant to be used to evaluate the effectiveness of training or other aspects of human performance.

A. DATA RESTRICTIONS

As assessment of training effectiveness must be based on comparative analysis limited to comparisons of performances of maintenance personnel on similar maintenance operations (i.e., similar processes applied to the same models of equipment) and where personnel are trained in the same skill area by different methods or to different extents. Verifying that these conditions are met places a series of constraints on the data developed through the management system, as follows:

- The data must measure the outcome of maintenance operations in terms that provide a criterion of maintenance personnel performance.
- The data must provide unambiguous (i.e., coded) answers to four questions regarding each maintenance operation:
  - --What equipment was maintained?
  - --Why was maintenance required (i.e., the nature of the equipment malfunction)?
  - --What was done to it (i.e., the nature of maintenance performed)?
  - --Who performed the maintenance?
- The data must separately document discrete and well-defined maintenance tasks that are comparable whenever they are performed on the same subsystem or assembly

(black box) installed on the same model of equipment end-items.

- The data must identify the equipment maintained at a sufficiently low level (e.g., subsystem or assembly) so that it can be associated with a single skill area related to specific training programs.
- The data must encompass a sufficiently wide set of maintenance tasks to provide a representative sample of the on-the-job skill requirements of a particular skill area.
- The data must identify organizations (or individuals) performing maintenance in a way that will allow their association with skill areas that can be related to specific training programs.

B. STRUCTURAL INCONSISTENCIES

There are four characteristics of military equipment, maintenance organization, and maintenance practice that, where they occur, are inconsistent with assessing training effectiveness from on-the-job performance data:

- Maintenance tasks may be performed by a group (or team) of personnel (i.e., team maintenance).
- Maintenance tasks associated with one skill area may be performed by personnel trained in a different skill area (i.e., cross-skill maintenance).
- Maintenance organizations may not be further structured into skill-related Work Centers.
- Not all military end-items or their installed subsystems are built to standard configurations.

These features are intractable constraints on assessing training effectiveness from on-the-job performance. However, maintenance reporting systems might be designed (or current systems modified) to identify where (on which maintenance tasks) they occur. Then, maintenance activity not associated with these constraints might shed light on training effectiveness.

C. ASSESSMENT OF MAINTENANCE MANAGEMENT SYSTEMS

Table 3 denotes, for each maintenance management system, the extent to which current system documentation conforms to the data restrictions discussed and where structural inconsistencies may prevent assessments of training effectiveness. It was developed through study of the systems' documentation and contact with knowledgeable service personnel. (Note that a notation in Part A of the table shows an <u>impediment</u> to assessing training effectiveness while a notation in Part B signifies data that <u>support</u> assessments.) For both types of characteristics the notations in the table give the maintenance systems (and the documentation they generate) the benefit of the doubt regarding their capabilities for assessing training effectiveness. That is, where uncertainties remained it was assumed that the requisite conditions for assessing training effectiveness were met.

1. <u>TAMMS</u>

TAMMS appears to provide no capability for assessing training effectiveness. The Army practices both team and cross-skill maintenance in peacetime since Army units will operate in that fashion under combat conditions. A major portion of Army maintenance units are not further structured into WCs so that there is no way to identify the skill areas of personnel performing maintenance. In addition, the maintenance reporting format has no provision for noting where team maintenance occurs.

2. <u>Ships' 3-M</u>

The Ships' 3-M system appears to provide no capability for assessing maintenance performance (and, hence, training effectiveness) for reasons that encompass both the nonstandard nature

TABLE 3. ASSESSMENT OF MAINTENANCE MANAGEMENT SYSTEMS

	TAMMS	Management System		
		Ships 3-M (Navy)	Aviation 3-M (Navy)	66-1/66-5 (USAF)
Part A:				
<u>Structural inconsistencies present</u>				
Team Maintenance	X	X	X	X
Cross-skill Maintenance	X			X
Maintenance Organizations Not Structured According to Skill-Area (i.e. WCs)	X		a	a
Non-standardized Equipment		X		
Part B:				
<u>Data requirements satisfied</u>				
Quantifies a Criterion of Performance	X	X	X	X
Coded Descriptions of Maintenance Performed				
• What Equipment was Maintained?	X	X	X	X
• What was wrong with it?	X		X	X
• What was done to it?	X		X	X
• Who Performed the Maintenance?	X	X	X	X
Maintenance "Task" Documentation	X		X	X
Equipment can be Identified with Skill Area	X	X	X	X
Recorded Maintenance Representative of Job Requirements[b]	X		X	X
Who Performed Maintenance can be Identified with Skill-Area		X[c]	X[d]	X[d]

[a] Some WCs are manned by personnel with training in several skill areas.

[b] <u>Recording</u> refers only to initial documentation of maintenance performed. A comprehensive capability for assessing training effectiveness would require that these data be reported to higher echelons.

[c] More than one WC, in the same skill area, may be involved in and identified with the documentation of one maintenance action.

[d] Except for WCs manned by personnel with training in different skill areas.

of shipboard equipment and the data reported. Except in the area of electronics and ordnance, shipboard systems are not standardized, and ships are not outfitted to standard configurations. Even if the configuration problem were not present, the data reported through the Ships' 3-M system appear inconsistent with assessing training effectiveness on three counts. First, maintenance reporting is notably incomplete and cannot be assumed to provide representative samples of the ranges of skills for which personnel are trained. Second, data are reported only for complete maintenance actions (as opposed to individual maintenance tasks). Finally, the English descriptions and code systems used to document maintenance are inadequate to identify comparable maintenance actions.

3. Aviation 3-M, 66-1, and 66-5

Even though the Air Force systems (66-1 and 66-5) employ the same data-reporting forms, they display quite different potentials for assessing training effectiveness. The 66-5 system appears to provide no potential for this assessment. Under the POMO structure the large majority of maintenance personnel are assigned to the organizational echelon where the development of cross-skill capabilities is a primary POMO policy. This policy might be implemented in several ways (e.g., by forming interskill maintenance teams, by assigning personnel to WCs other than those for which they have been trained). Maintenance data reporting appears to provide no way to identify cross-skill work that is promoted by these means. In addition, it is possible that cross-skill maintenance might be prevalent to the point where a satisfactory sample of in-skill maintenance could not be obtained.

The 66-1 and Aviation 3-M systems may provide a restricted capability for assessing training effectiveness if occurences of team and cross-skill maintenance could be unambiguously identified and eliminated from analyses. This might be possible by making some seemingly modest changes to the data reported and by supplementing these data with information that is normally available in unit roster and personnel record systems. Whether the reporting system changes and supplementary data suggested here will, in fact, provide this identification requires inquiry into maintenance operations to a depth not accomplished in this study.

a. Team Maintenance. The 66-1 system currently documents maintenance "crew size" and start/stop times and notes all crew changes and work interruptions that occur during the course of a maintenance task. These data appear to provide a satisfactory separation of team from individually performed tasks. However, it is not clear whether the separation provided by these data (along with other data contained in maintenance records) are reliable for all possible types of maintenance and the various conditions under which they may be performed (e.g., shift changes, interruptions for lack of parts, changes in malfunction diagnosis). Aviation 3-M currently provides no permanently retained information regarding the number of individuals contributing to a maintenance task. However, the similarities in equipments, their maintenance requirements, and maintenance organization between USAF and Naval aircraft appear sufficient to propose that whatever data and formats would identify team maintenance in the 66-1 system would serve the same purpose in the Aviation 3-M system.

b. Cross-skill Maintenance. Both equipments and WCs appear relatable to skill areas in the Aviation 3-M and 66-1 systems so that occurences of cross-skill work should be identifiable. However, a number of exceptions were noted in examples contained in the Aviation 3-M user manuals that cast doubt on the validity of this conclusion. The extent to which WCs, in fact, specialize in one skill area (1) may vary among maintenance organizations as functions of size, equipment maintained, and command decision; (2) will vary among the different WCs within maintenance organizations; and (3) may vary over time within the same WC as a function of service-wide personnel availabilities. Further, personnel may be temporarily transferred between WCs that are associated with quite different skill areas as a result of workload variations. Similarily, the extent to which skill-areas can be associated with WCs varies. All such variations, whether they constitute normal practices or exceptions, weaken the case for identifying cross-skill maintenance, especially where the variations are systematic.

c. Reporting System Changes. The uncertain identification of both team and cross-skill maintenance might be considerably strengthened if data records were to specifically identify all personnel engaging in a maintenance task. While identifying personnel in the central maintenance data files conflicts with provisions of the Privacy Act, it should be possible to name individuals in local unit records and then to process these records in ways that would provide suitable identification for analyses of training effectiveness while being consistent with the Act. For example, individuals could be preselected for analysis of performance on the basis of training and experience information in personnel records. Look-up tables could be established or special notations (flags) could be attached to their names or identification numbers as a device for identifying the maintenance tasks they subsequently perform. Where maintenance documentation identified these individuals and where neither team nor cross-skill maintenance was indicated, the records would be duplicated for analysis of performance, and the identification of individuals could then be deleted from the maintenance records submitted to central files.

Analyses of training effectiveness could then be performed without interfering with either the current maintenance management systems or the organization of maintenance. ADP of the Aviation 3-M system is currently being modified to accomplish on-line record entry and updating (instead of hardcopy and punched card) as part of the Navy Air Logistics Command Management Information System (NALCOMIS) program. As presently designed, local unit on-line records will identify personnel by name, and this information will be dropped when the local records are committed to the Aviation 3-M central tape files. It appears to be a feasible further step to provide identification in a way that would allow selection of the on-line records for performance analysis. An added benefit of this approach would be that analyses could proceed more directly--without the intermediate step of modelling and regression analyses.

With these changes, the nagging question remains of whether the resulting samples would be representative of the job requirements of skill areas. The prospects are not promising, especially at the organizational echelon. An analysis that concentrated on recently trained personnel would be essentially limited to personnel who are not qualified for independent work on aircraft equipment. The Air Force has a service-wide procedure for job qualification that consists of structured OJT and performance examinations, and personnel are not permitted to perform independent work until specifically qualified. (The Navy also has defined qualification standards and OJT programs, although the Navy program is less restrictive regarding the work which can be accomplished by new personnel.) It could well be that by the time an individual meets the qualification standards for independent work the impact of different formal training programs would be diluted to the point where initial differences in performance that were due to the training would be washed out.

GLOSSARY

Cross-Skill Maintenance: Performance of maintenance that is associated with one skill area by personnel that are trained in a different skill area.

Maintenance Action: All effort associated with a maintenance requirement that permits equipment to be returned to operational status.

Maintenance Task: Individual well defined maintenance procedures that are parts of maintenance actions.

Off-equipment Maintenance: Maintenance performed on equipment systems and assemblies that have been removed from weapon end-itmes.

On-equipment Maintenance: Maintenance performed on equipment systems and assemblies while they are installed on weapon end-items.

Team Maintenance: Separately documented maintenance actions or tasks that are performed by more than one person.

End-item: The combination of systems, components, and/or material that is complete for its intended use, e.g., ship, tank, aircraft, mobile machine shop.

ACRONYMS

AAC	Alaskan Air Command
ADP	Automatic Data Processing
AMES	Aircraft Maintenance Effectiveness Simulation
AN	Army Navy
APL	Authorization Parts List
AT	Action Taken
CB	Component Breakdown
DCNO	Deputy Chief of Naval Operations
DCS	Deputy Chief of Staff
DS	Direct Support
EIC	Equipment Identification Code
GS	General Support
HHC	Headquarters/Headquarters Company
IMA	Intermediate Maintenance Activity
JCN	Job Control Number
MAC	Military Airlift Command
MDS	Model/Designation/Series
Mk/Mod	Mark/Model
Mil Std	Military Standard
MOS	Military Occupational Specialty
NALCOMIS	Navy Air Logistics Command Management Information System
NAMP	Naval Aviation Maintenance Program
NAVAIR	Naval Air Systems Command
NIP	NAMP Improvement Program
NORM	Not Operationally Ready - Maintenance
NSN	National Stock Number
OJT	On-The-Job Training
PACAF	Pacific Air Forces
POMO	Production Oriented Maintenance Organization

SAC	Support Action Code
SDC	Sample Data Collection
SEL	Selected Equipment List
TAC	Tactical Air Command
TAMMS	The Army Maintenance Management System
TM	Type Maintenance
USAFE	United State Air Forces in Europe
WC	Work Center
WUC	Work Unit Code
3-M	Maintenance and Material Management
66-1	The Air Force maintenance management system employed by all Air Force organizations other than units of the Tactical Air Forces. The name is derived from the number of the Air Force regulation and manual that sets out maintenance policy under this system.
66-5	The Air Force maintenance management system employed by units of the Tactical Air Forces (AAC, PACAF, TAC, USAFE) that are organized according to the POMO concept. The name is derived from the number of the Air Force regulation and manual that sets out maintenance policy under this system.

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APPENDIX

DATA RECORDING FORMS

APPENDIX

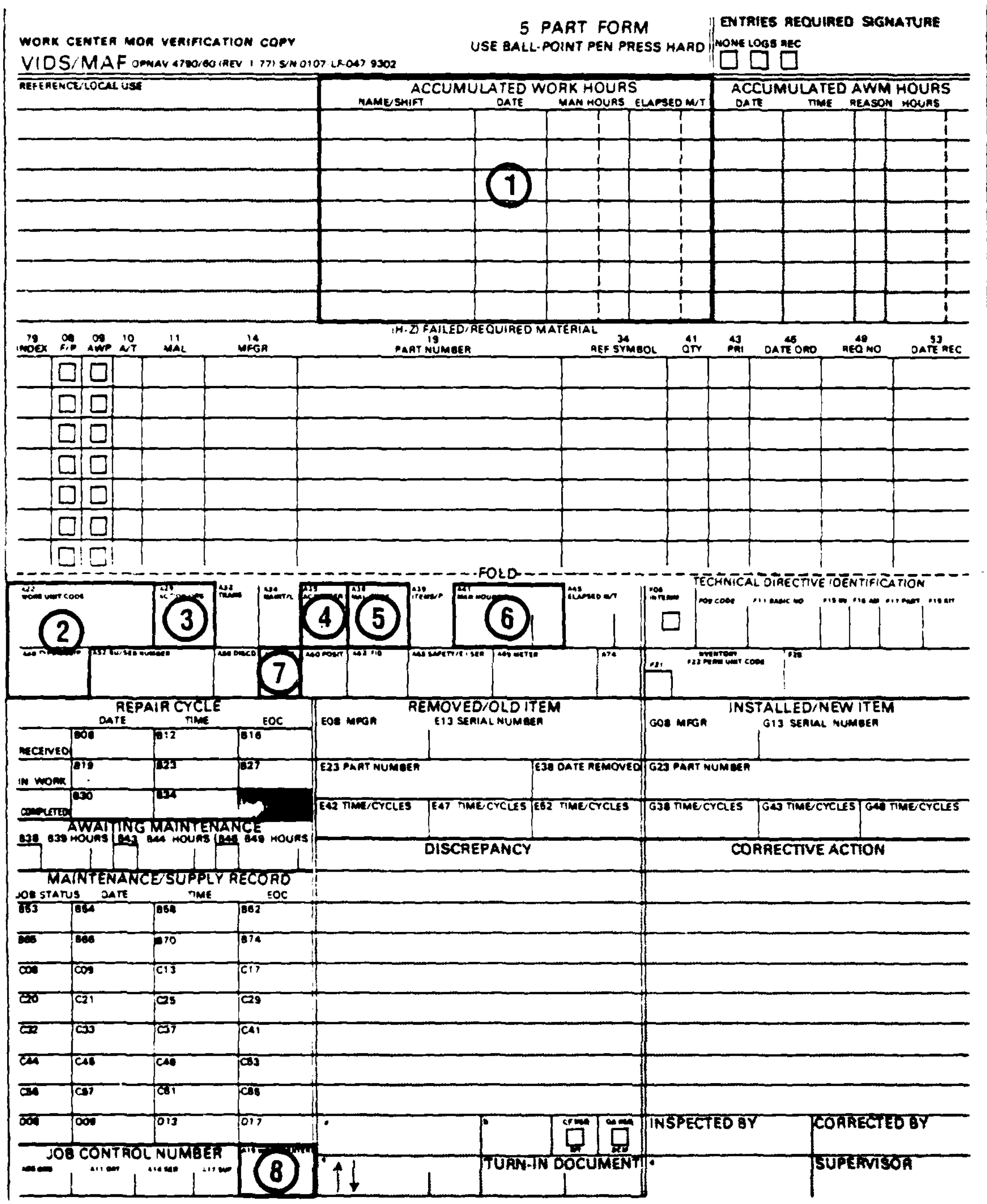
DATA RECORDING FORMS

This appendix discusses the forms on which maintenance data are recorded in each of the management systems. The forms reflect the major functions of the systems (daily management of maintenance operations, configuration control, and material support and control), and a limited fraction of the recorded information bears directly on answering the four basic questions relevant for assessing maintenance performance and training effectiveness. In the displays of the data recording forms, those fields that are considered relevant for assessing training effectiveness are outlined and numbered, and the numbers serve as references in the subsequent discussions. For the three systems that employ EDP (Ship's 3-M, Aviation 3-M, and 66-1/66-5) the data fields that neither are transcribed to EDP records nor are relevant for assessing training effectiveness have been shaded.

A.1 NAVAL AVIATION 3-M

The VIDS/MAF form, Figure A-1, is used for recording information on all corrective maintenance and the look-phase of major inspections. All information transfered to EDP consists of code values (either codes developed specifically for recording maintenance information or codes that serve other purposes such as part and manufacturer numbers) and numeric values such as dates and quantities.

The equipment maintained is identified by the WUC value for the specified type of equipment (end-item), (2). The reason



8-26-81-4

Figure A-1. VIDS/MAF Form

maintenance is performed is given by the malfunction code, 5. What was done in the course of the maintenance is described by the action taken 4 and type maintenance 7 codes. Who performs maintenance is identified by the combination of work center 8 and the maintenance organization to which it belongs 3. Total man-hours expended on the task are recorded in 6. The individuals performing maintenance, along with the man-hours expended by each, are separately identified in the "accumulated work hours" section 1; however, this information is not transfered to EDP records.

A.2 AIR FORCE 66-1 AND 66-5

The Maintenance Data Collection Record (Figure A-2) is used to record all maintenance in the 66-1/66-5 systems. Equipment being maintained is identified by the values of the WUC 4 and the SRD 2. (SRD, or Standard Reporting Designator, is a three character code that denotes the type of equipment end-item.) What is wrong with the equipment is given by the how-malfunction code 6. What was done in the course of maintenance is contained in the type-maintenance 3 and action-taken 5 codes. Who performed the maintenance task is identified through the combination of work center 1 and the maintenance organization containing the work center, where the identification of the organization is provided by the processing routines that transfer the hard-copy information to EDP records. Man-hours expended are calculated during initial EDP from the start-hour, stop-hour, and crew size values contained in 7. A separate line of information is recorded each time there is a change in any of the columns A through N, including changes in crew size or composition, and each line results in a distinct EDP record. Employee number 8 typically names a shop supervisor or lead technician and should not be a reliable guide to identifying individuals actually performing maintenance; in addition, this information is not transfered to EDP records.

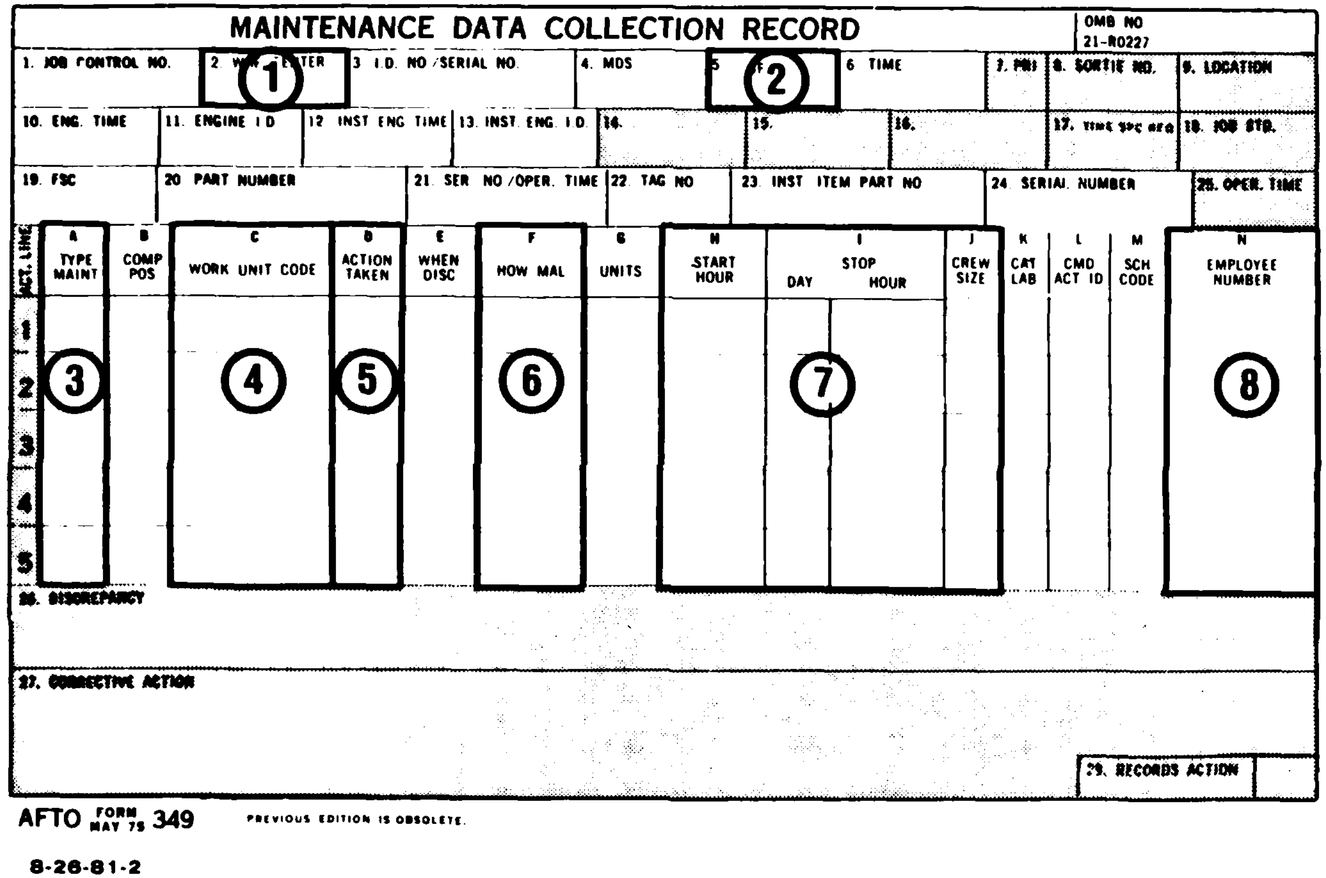


Figure A-2. Maintenance Data Collection Record

29 PARTS REPLACED DURING REPAIR (SUBASSEMBLIES REPAIRED/REPLACED)						
LINE NO.	A FSC	B PART NUMBER	C WORK UNIT CODE	D REF SYMBOL	E HOW MAL	F QTY

30. CONTINUATION FROM BLOCK ....

☆ U.S. Government Printing Office:1977-759-,50/1.

8-26-81-3

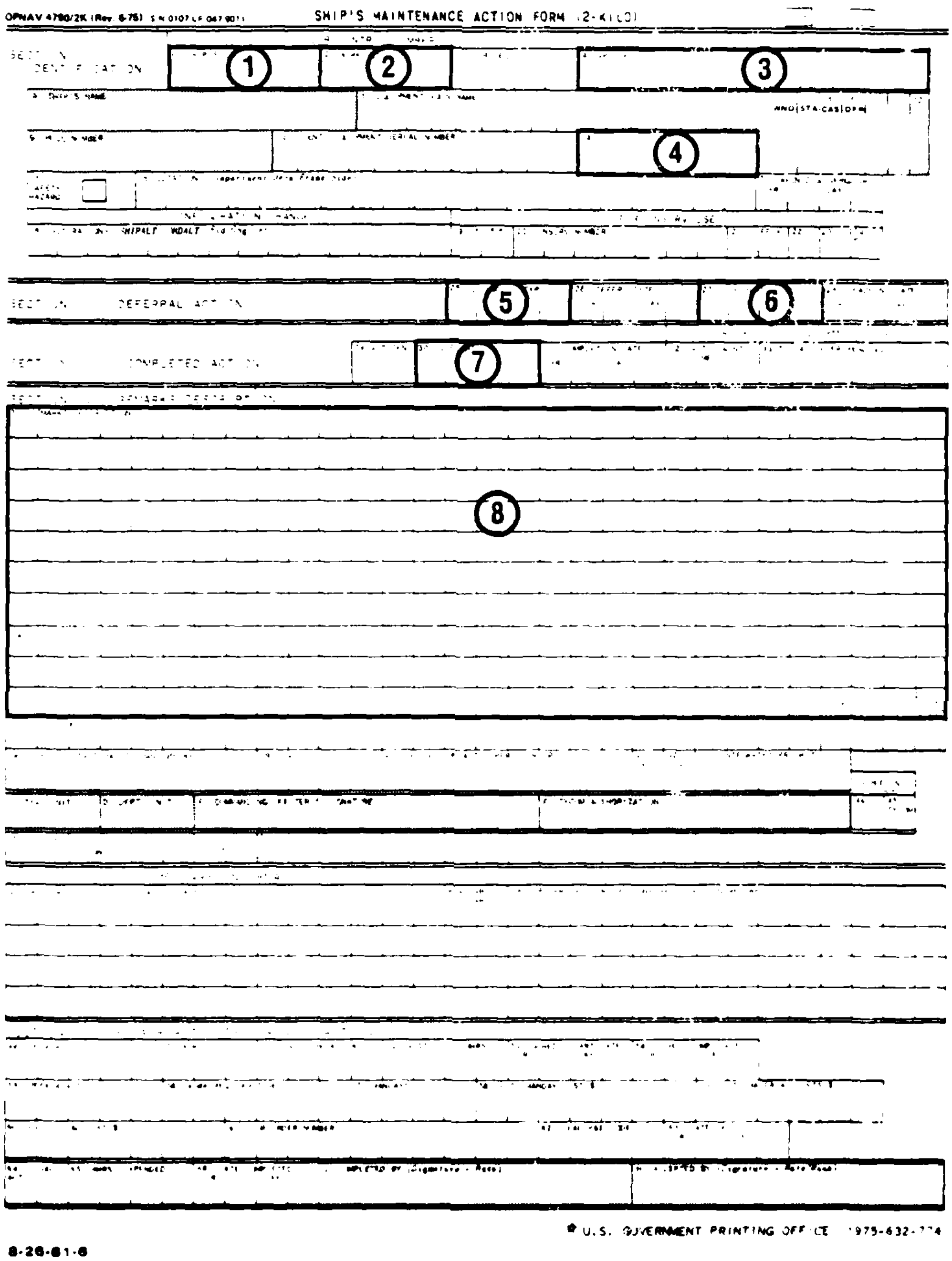
Figure A-2 (Continued). Back of Maintenance Data Collection Record

A.3 NAVY SHIP'S 3-M

Several reporting forms are employed in the Ship's 3-M system, and the same information may be displayed on different forms. Two of these forms are completed manually by ships force and/or IMA personnel and serve to initiate EDP records of maintenance actions. The EDP records may be updated and used to generate work status reports before the maintenance is completed and as a final report upon completion.

All information pertaining to maintenance actions that are completed by ship's force personnel is manually recorded on the Ship's Maintenance Action Form (2-KILO), Figure A-3, and all but a few items are transcribed to EDP records. The equipment being maintained is identified by either or both the APL or EIC, 3 and 4. The remarks description section, 8 allows for English descriptions of information not provided for in other sections of the form; this is the only place for describing what was wrong with the equipment and what was done to effect repair. (The EDP records permit descriptions up to 1200 characters.) Identification of who performed the maintenance is accomplished through the combination of the ship's identification code number (UIC) and the performing WC, 1 and 2. Where maintenance is deferred, the ship's force man-hours expended to the date of deferral are recorded at 5 and an estimate of the man-hours required for completion is recorded at 6. When a deferred action is completed, the total ship's force man-hours expended are recorded at 7.

When a maintenance action is completed with IMA assistance the second manual form is completed by IMA personnel for planning/scheduling of the IMA effort. The information contained on the Ship's Maintenance Action Form and the planning/scheduling information are consolidated into a single EDP record (the



OPNAV 4790/2K (Rev. 6-75) S/N 0107-LF-047-9011

SHIP'S MAINTENANCE ACTION FORM (2-KILO)

SECTION I IDENTIFICATION

1 2 3 4

SAFETY HAZARD

SECTION II DEFERRAL ACTION

5 6

SECTION III COMPLETED ACTION

7

8

U.S. GOVERNMENT PRINTING OFFICE 1975-632-774

8-26-81-6

Figure A-3. Ship's Maintenance Action Form (2 KILO)

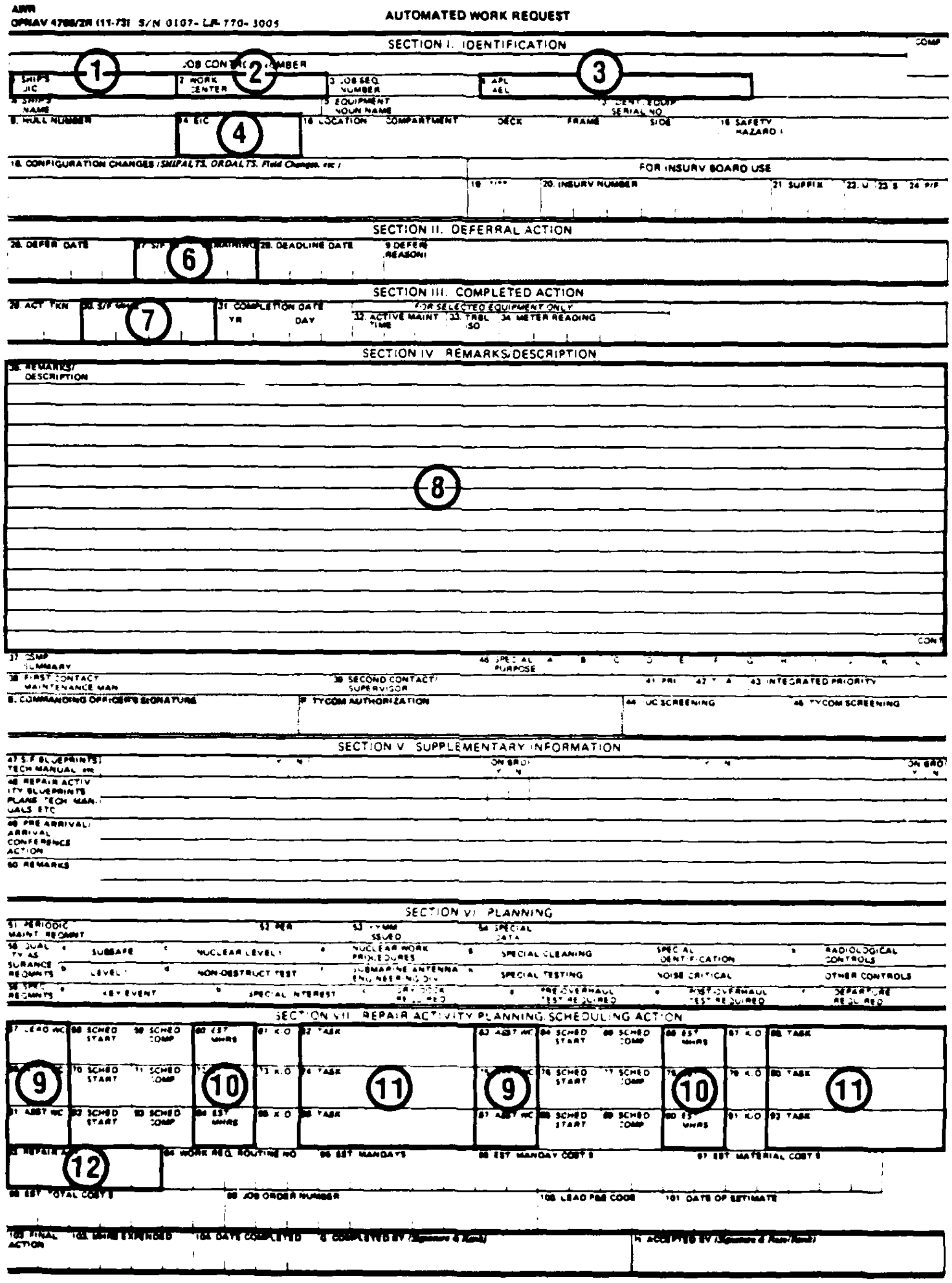
3-M Master Record). This record is used to generate the Automated Work Request, Figure A-4, and contains all but a few of the data items contained in the 3-M Master Record.

The 3-M Master Record contains all of the items in the Ship's Maintenance Action form (2-KILO) that are considered as possibly useful for assessing training effectiveness, and the Automated Work Request displays all but one of these items, the ship's force man-hours expended through the date of deferral (5). In addition it displays information regarding the IMA assistance provided, including identification of the IMA (12) and its various WCs providing the assistance (9), the man-hours expended by each of the IMA WCs (10), and a cryptic description of the task performed by each (11). At the completion of the maintenance action the 3-M Master Record (from which the Automated Work Request is generated) documents the total effort expended by both the IMA and the tended ship.

A.4 ARMY TAMMS

In TAMMS all maintenance data are recorded on the Maintenance Request, DA Form 2407, Figure A-5. Reasons for performing maintenance are given by the Failure Code (6); what was done to effect repairs is given by the Action Code (5); the man-hours expended are shown in (9). Each change in the action or failure codes (or the component, assembly, or piece part of equipment involved in the maitenance) is documented on a separate line of these fields. This provides for separate documentation of the individual maintenance tasks while one Maintenance Request form can encompass a complete maintenance action.

Identification of who performs maintenance is accomplished by the Unit Identification Code assigned to all Army units. Where maintenance is accomplished at the intermediate echelon (DS or GS) the code of the performing unit is entered in (4). For organizational echelon maintenance, the code of the performing


AWR
OPNAV 4790/2R (11-73) S/N 0107-LF-770-3005
AUTOMATED WORK REQUEST

SECTION I. IDENTIFICATION
JOB CONTROL NUMBER
1 SHIPS UIC | 2 WORK CENTER | 3 JOB SEQ. NUMBER | APL AEL
SHIPS NAME | 5 EQUIPMENT NOUN NAME | IDENT. EQUIP SERIAL NO
HULL NUMBER | EIC | LOCATION | COMPARTMENT | DECK | FRAME | SIDE | SAFETY HAZARD
18. CONFIGURATION CHANGES (SHIPALTS, ORDALTS, Field Changes, etc.)
FOR INSURV BOARD USE
20. INSURV NUMBER | 21 SUFFIX

SECTION II. DEFERRAL ACTION
26. DEFER DATE | REMAINING | 28. DEADLINE DATE | DEFER REASON

SECTION III. COMPLETED ACTION
ACT TKN | 31 COMPLETION DATE YR DAY | FOR SELECTED EQUIPMENT ONLY | 32. ACTIVE MAINT TIME | 33. TRBL ISO | 34. METER READING

SECTION IV REMARKS/DESCRIPTION
REMARKS/ DESCRIPTION
COMP SUMMARY | SPECIAL PURPOSE
FIRST CONTACT MAINTENANCE MAN | SECOND CONTACT/ SUPERVISOR | INTEGRATED PRIORITY
COMMANDING OFFICER'S SIGNATURE | TYCOM AUTHORIZATION | UC SCREENING | TYCOM SCREENING

SECTION V SUPPLEMENTARY INFORMATION
S.F. BLUEPRINTS/ TECH MANUAL, etc.
REPAIR ACTIVITY BLUEPRINTS PLANS TECH MANUALS ETC
PRE ARRIVAL/ ARRIVAL CONFERENCE ACTION
REMARKS

SECTION VI PLANNING
PERIODIC MAINT REQMNT | SPECIAL DATA
SUBSAFE | NUCLEAR LEVEL I | NUCLEAR WORK PROCEDURES | SPECIAL CLEANING | SPECIAL IDENTIFICATION | RADIOLOGICAL CONTROLS
LEVEL I | NON-DESTRUCT TEST | SUBMARINE ANTENNA ENGINEERING DIV | SPECIAL TESTING | NOISE CRITICAL | OTHER CONTROLS
KEY EVENT | SPECIAL INTEREST | DRY DOCK REQUIRED | PRE-OVERHAUL TEST REQUIRED | POST-OVERHAUL TEST REQUIRED | DEPARTURE REQUIRED

SECTION VII REPAIR ACTIVITY PLANNING SCHEDULING ACTION
LEAD WC | SCHED START | SCHED COMP | EST MHRS | K.O. | TASK
ASST WC | SCHED START | SCHED COMP | EST MHRS | K.O. | TASK
WORK REQ. ROUTINE NO | EST MANDAYS | EST MANDAY COST $ | EST MATERIAL COST $
EST TOTAL COST $ | JOB ORDER NUMBER | LEAD P&E CODE | 101 DATE OF ESTIMATE
FINAL ACTION | MHRS EXPENDED | 104 DATE COMPLETED | COMPLETED BY (Signature & Rank) | ACCEPTED BY (Signature & Rate/Rank)

8-28-81-7

Figure A-4. Automated Work Request

MAINTENANCE REQUEST
For use of this form, see TM 38-750; the proponent agency is Office of the Deputy Chief of Staff for Logistics.

*See reverse of file copy for codes and additional data. | PAGE NO | NO OF PAGES | REPORTS CONTROL SYMBOL CSGLD-1047 (R1)

SECTION I — WORK REQUEST — MWO — EIR — ORGANIZATION ISSUE PRIORITY DESIGNATOR CODE

CONTROL NUMBER | 1a. ORGANIZATION | b. LOCATION | c. UNIT IDEN CODE (1)

2. SERIAL NUMBER | 3. NOUN NOMENCLATURE | 4. LINE NUMBER | 5. MODEL | (2) 6. NATIONAL STOCK NUMBER

7. MAINTENANCE ACTIVITY | 8. UTILIZATION CODE* | 9. SELECTED ITEM: 1 YES, 2 NO | 10. HOURS | 11. MILES | 12. ROUNDS | 13. STARTS

14. FAILURE DETECTED DURING (Select one - use √ or X): A SCHEDULED MAINTENANCE, B HANDLING, C TEST, D NORMAL OPERATION, E STORAGE, F INSPECTION, G FLIGHT, H OTHER

15. FIRST INDICATION OF TROUBLE (Select one - use √ or X): 088 INOPERATIVE, 006 NOISY, 258 OVERHEATING, 567 LOW PERFORMANCE, 790 OUT OF ADJUSTMENT, OTHER

16. DESCRIBE DEFICIENCIES OR SYMPTOMS ON THE BASIS OF COMPLETE CHECKOUT AND DIAGNOSTIC PROCEDURE IN EQUIPMENT TM (Do not prescribe repairs)

(3)

SECTION II. WORK ACCOMPLISHED

17a. REPAIR ORGANIZATION/ACTIVITY | c. UNIT IDEN CODE (4) | 18. TYPE ORGANIZATION/ACTIVITY ACCOMPLISHING WORK (Select one - use √ or X): TOE, TD, 3 CONTRACTOR | 19. AMS ACT. CODE

b. LOCATION

20a. ACTION CODE (5) | b. FAILURE CODE* (6) | c. COMPONENT/PART NOUN, SERVICE, OR MWO NO: d. CB CODE (7), e. REFERENCE DESIGNATOR, f. MFR CODE (8) | g. MANHOURS* (9) | h. NATIONAL STOCK NUMBER (10) | i. QUANTITY | j. PARTS COST

TOTAL MANHOURS | TOTAL MANHOURS COST | TOTAL PARTS COST

21. DELAY (Select one - use √ or X): 1 PARTS, 2 MANPOWER, 3 FACILITIES, 4 FUNDS, 5 TOOLS | 22. DATA TRANSCRIBED TO LOG BOOK

23. SUBMITTED BY | 24. RECEIVED BY | 25. WORK STARTED BY | 26. INSPECTED BY | 27. ACCEPTED BY | 28. DISPOSITION (Select one - use √ or X): A TO USER, B TO STOCK, SALVAGED, EVALUATED, CANNIBALIZATION

JULIAN DATE | JULIAN DATE | JULIAN DATE | JULIAN DATE | JULIAN DATE

SECTION III. EQUIPMENT IMPROVEMENT RECOMMENDATION

29. NORMAL REPLACEMENT (Select one - use √ or X): YES, NO | 30. EIR (Select one - use √ or X): EMERGENCY, URGENT, ROUTINE | 31. RECOMMENDATION (Select one - use √ or X): IMPROVE DESIGN, MODIFY, REVISE PROCEDURE, OTHER (Specify) | 32a. ORGANIZATION/ACTIVITY, UNIT IDEN CODE, b. LOCATION, c. SUBMITTED BY

33. NATIONAL STOCK NUMBER | 34. NOUN NOMENCLATURE | 35. OPINION OR REMARKS. DESCRIBE CONDITIONS UNDER WHICH FAILURE OCCURRED. ATTACH PHOTOS OR SKETCHES IF AVAILABLE

DA FORM 1 OCT 73 2407 — EDITION OF 1 JAN 64 WILL BE USED UNTIL EXHAUSTED — CONTROL COPY 3

8-26-81-6

Figure A-5. Maintenance Request, DA Form 2407 unit is entered in 1 and 4 and will be blank. However, with the current Army management structure the lowest echelon unit assigned a Unit Identification Code will likely be the equipment custodian, responsible for both equipment operations and all maintenance (e.g., a tank company containing both operating and maintenance sections or a tank battalion that contains a maintenance platoon to provide support to both its own equipment and the equipment of the tank companies it contains). (Note that block 7 of the form, maintenance activity, is limited to identifying the echelon at which the maintenance is accomplished.)

The way in which equipment being maintained is identified will differ, depending upon whether on-equipment or off-equipment maintenance is performed and, for on-equipment work, whether aircraft or ground equipment is involved. As a result, the labelling of the columns and boxes, especially block 20 of the form, may not reflect the data they actually contain. The data contained in relevant sections of the form are summarized in Table A-1 and discussed below.

Table A-1. IDENTIFICATION OF EQUIPMENT MAINTAINED

	Off-Equipment Maintenance	On-Equipment Maintenance	
		Aircraft	Ground Equipment
End-Item	-	2	2
Subsystem (of End-Item)	-	7	-
System Removed (From End-Item)	3	-	-
Component/Assembly of System Removed	2	-	-
Assembly or Parts Repaired and/or Replaced	8 & 10	8 & 10	8 & 10

For off-equipment maintenance, the NSN of the system removed from an end-item (e.g., a communication set) is inserted at (3), and the model name and NSN of the component or assembly of the system that is actually undergoing maintenance (e.g., the transmitter section of the communication set) is inserted at (2). For individual maintenance tasks that pertain to the assembly as a whole (e.g., adjustment or inspection) (8) and (10) will also show the model name and NSN of the assembly; for tasks involving replacement of parts within the assembly, the names of the parts and their NSNs will be inserted in (8) and (10).

For on-equipment maintenance of aircraft, the model number and NSN of the aircraft (i.e., the end-item) will be contained by (2), and identification of the subsystem requiring maintenance will be provided by the CB code (similar to the first two digits of Navy and Air Force WUCs) at (7). (8) will contain a description of individual maintenance tasks performed or parts replaced, and where parts are used, (10) will contain the NSN of those parts. For ground equipment (2) will contain the model number and NSN of the end-item. (8) will contain the name of the system, assembly or part undergoing repair or being replaced. When an assembly or part is replaced (10) will contain its NSN.